AUTOMOBILE ENGINEER

DESIGN · PRODUCTION · MATERIALS

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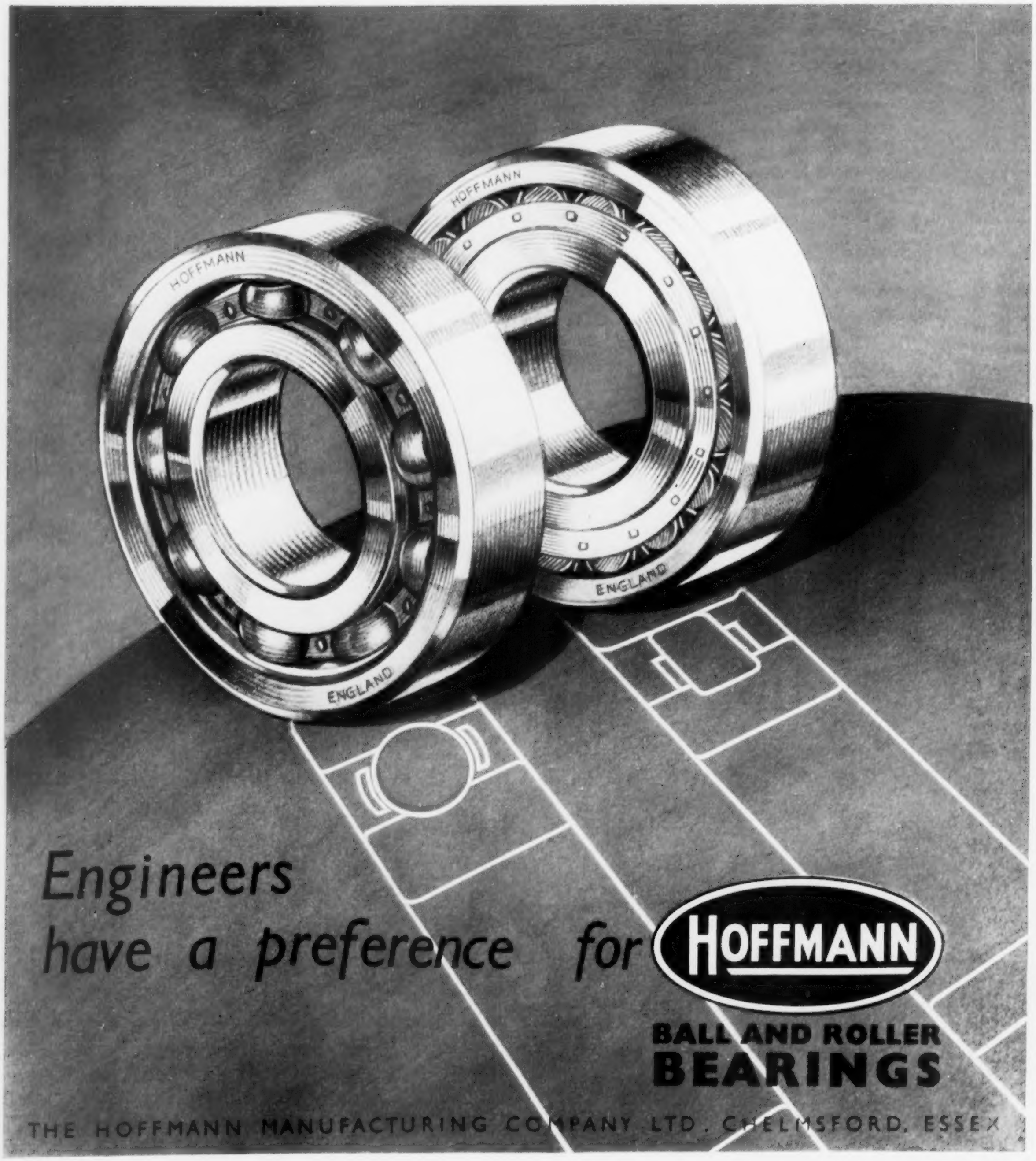
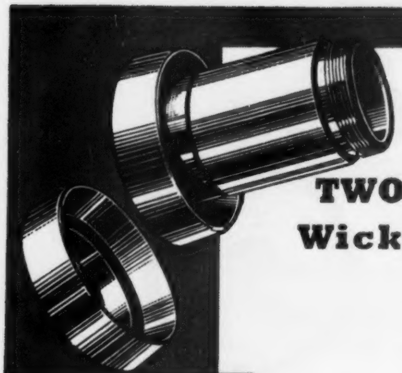


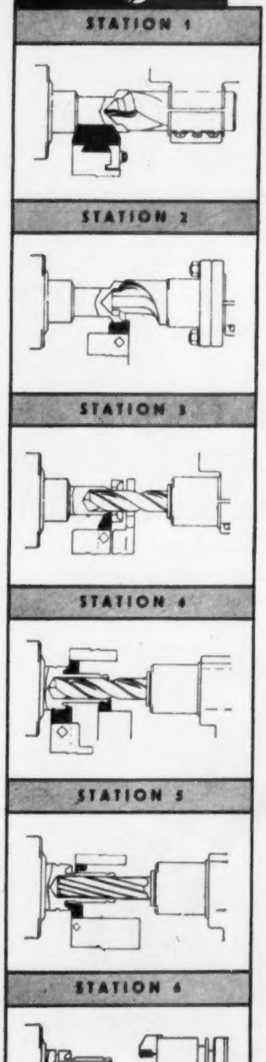

A
Standard
Fitting
When high performance counts you can rely on
MINTEX
The Standard Motor Co. Ltd.
specifies Mintex Brake and
Clutch Liners for their
Eight and Ten cars
Mintex Brake and Clutch Liners are manufactured by British Belting & Asbestos Limited and are AVAILABLE FROM OUR STOCKISTS AND AT LEADING GARAGES THROUGHOUT THE COUNTRY.



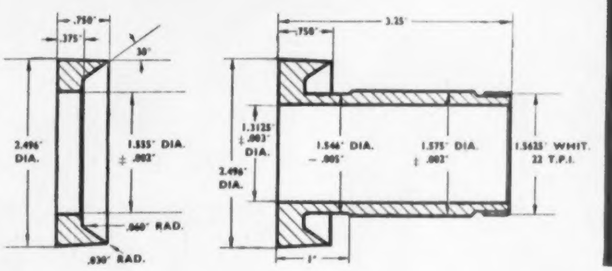
Another user gets an output bonus!

TWO PARTS produced together on the Wickman Multi-spindle Automatic

in 91 seconds

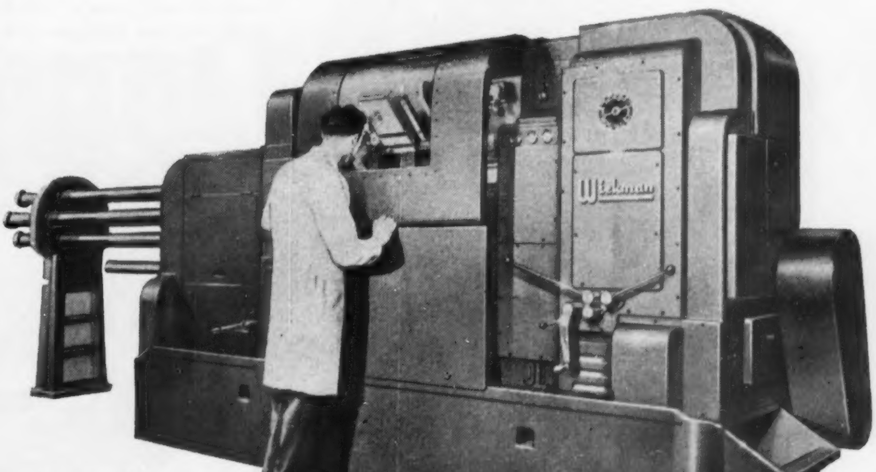


Commutator Hub and Clamping Ring (Mild Steel).



So often the production engineer thinks in terms of one part, and one machine to make it . . . and although it may be the exception rather than the rule to make two parts together on a Wickman Automatic, this example demonstrates the outlook of Wickman Engineers in planning for maximum machine utilisation, and the exceptional tooling opportunities offered by the range of Multi-spindle Automatics.

Whether you're looking for higher output, or putting new parts into production, it will pay you to let Wickman engineers investigate the possibilities of tooling up a Multi-spindle Automatic to meet your requirements. Remember, there are no expensive interchangeable cams to design and make; by means of the Wickman patent autosetting mechanism all tool feed strokes and bar feed can be set in a matter of minutes, and a wide range of standard attachments is available.



Wickman 2$\frac{5}{8}$"—6 Spindle Bar Automatic.

WICKMAN of COVENTRY

LONDON · BRISTOL · BIRMINGHAM · MANCHESTER
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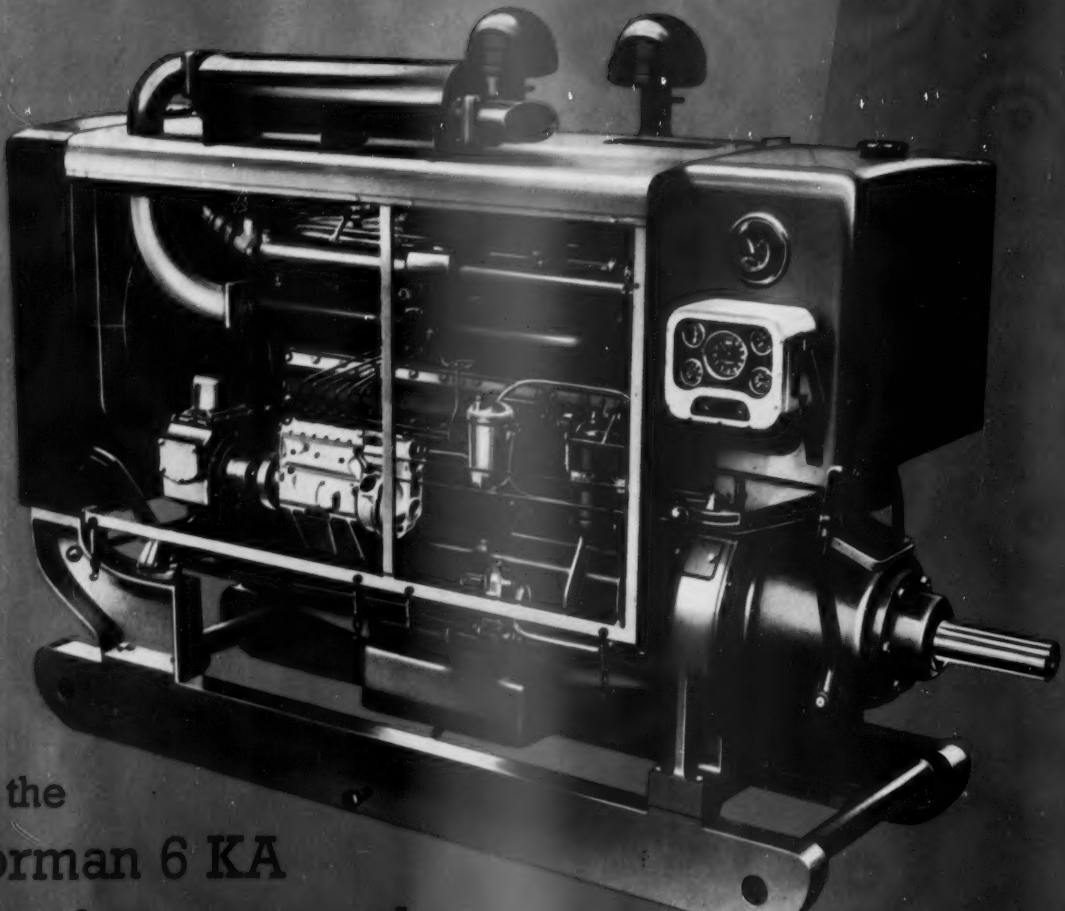
Wickman

326WM



On the
Dorman 6 KA diesel power pack

This compact oil-engined power pack is equipped with the Rockford clutch and power take-off.

The Rockford clutch has a balanced toggle-action which holds the clutch firmly in the engaged or the disengaged position without running thrust, and a simple and accessible adjusting device, shown below, which is self locking without the need for special tools.

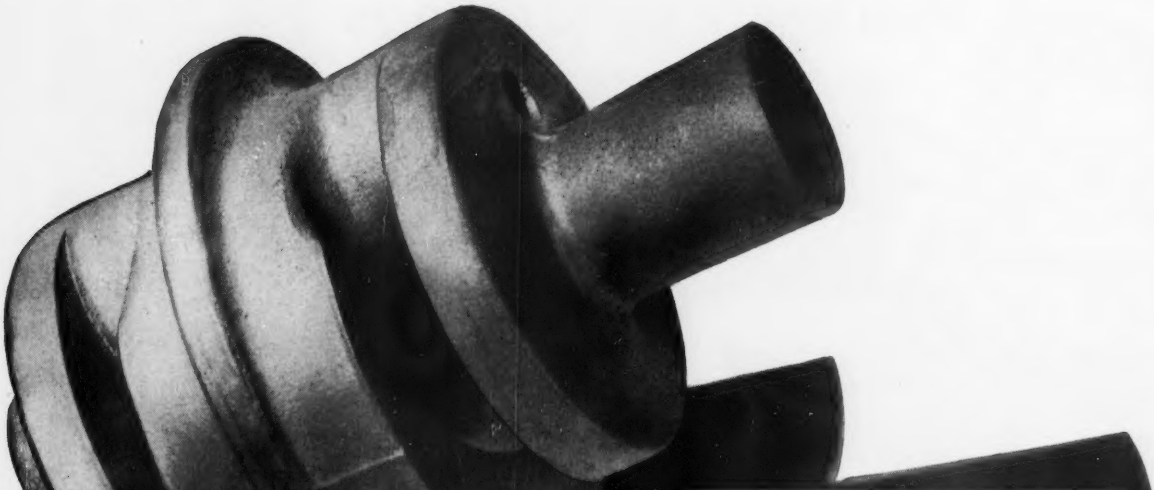
The Rockford clutch and the power take-off are being used extensively on various kinds of industrial equipment.

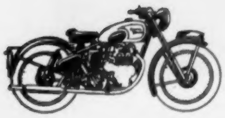
British made, in a range of sizes, by
Borg & Beck Company Limited,
Leamington Spa, England.

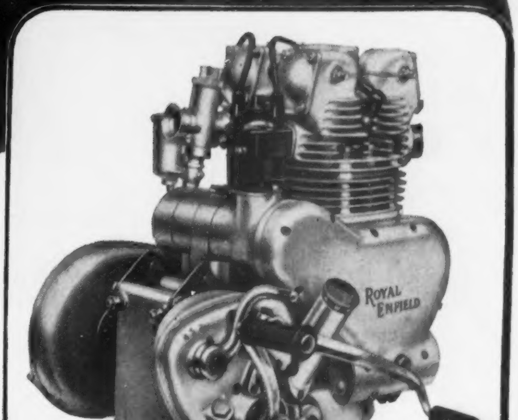
ROCKFORD

POWER TAKE-OFFS & CLUTCHES

Royal Enfield are making sure with HARPER quality







The engine of the Royal Enfield "500 Twin" motor-cycle in standard trim develops 25 B.H.P. at 5,750 R.P.M. and can reach 7,000 R.P.M. The crankshaft is a Harper casting. The Enfield Cycle Co. Ltd. say: "The excellent machining properties of the material, together with its mono-bloc construction, make this a much simpler production proposition than a built-up crankshaft, besides ensuring that it runs dead true at all times."
Harper quality covers iron castings, and also metal pressings, machining, enamelling and other finishes and sub-assembly work.

HARPER CASTINGS

CASTINGS WITH THE HARPER SKIN

JOHN HARPER & CO. LTD. JOHN HARPER (MEEHANITE) LTD.
ALBION WORKS Phone: WILLENHALL 124 (5 lines) Grams: HARPERS, WILLENHALL **WILLENHALL**

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H. 314

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reliable Springs by

From the high precision spring required for a printing press to its simpler counterpart in a fountain pen, the right spring for the job is essential to ensure perfect performance. When your springs are designed and made by Salter, they are just right — not the cheapest obtainable but fit to work for ever.

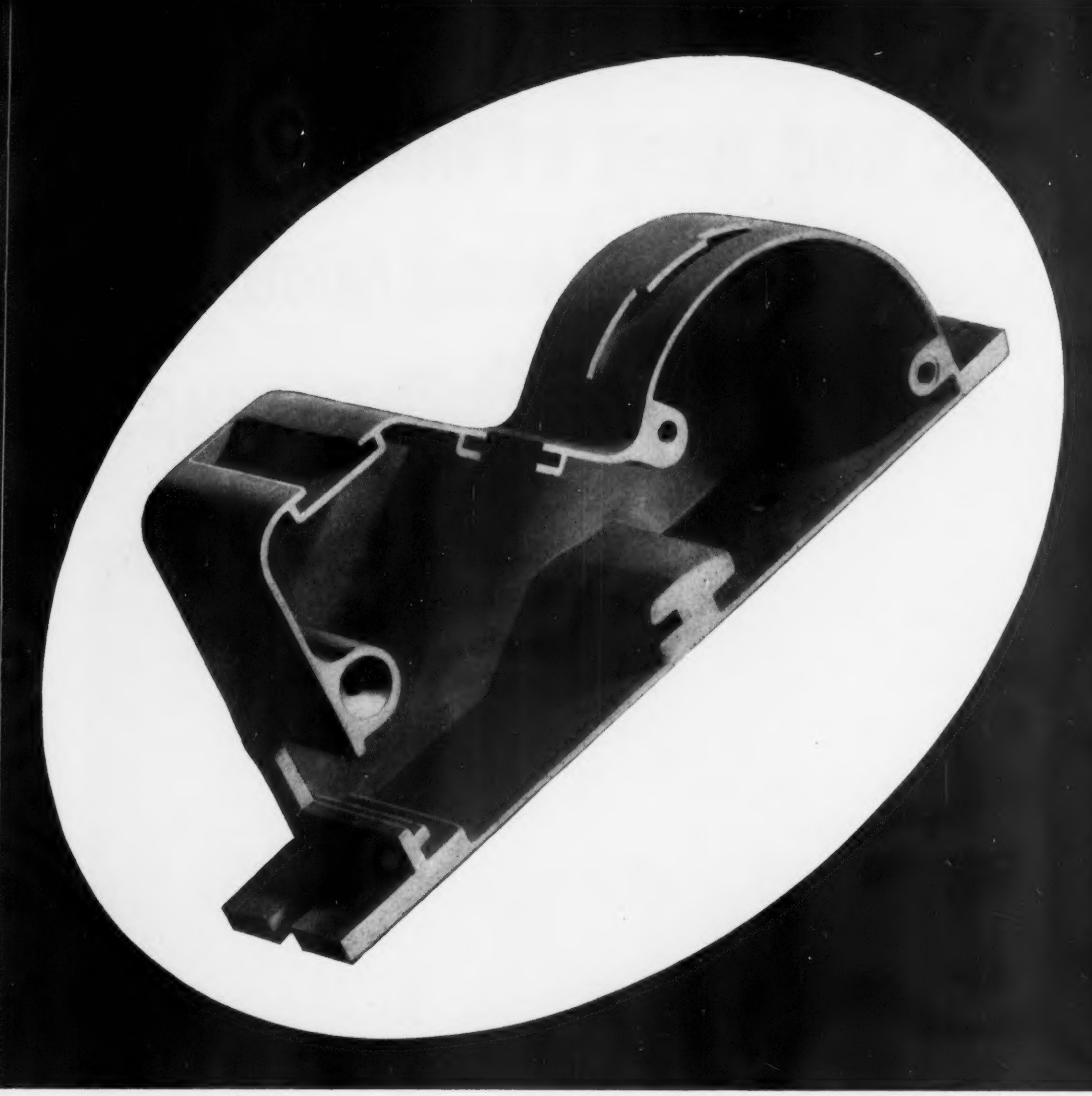
SALTER

Service to Engineers since 1760

A tradition of quality in craftsmanship and materials is embodied in every Salter spring — you can depend on Salter for the *right spring for the job*.

Geo. Salter & Co. Ltd., West Bromwich

M-W.387



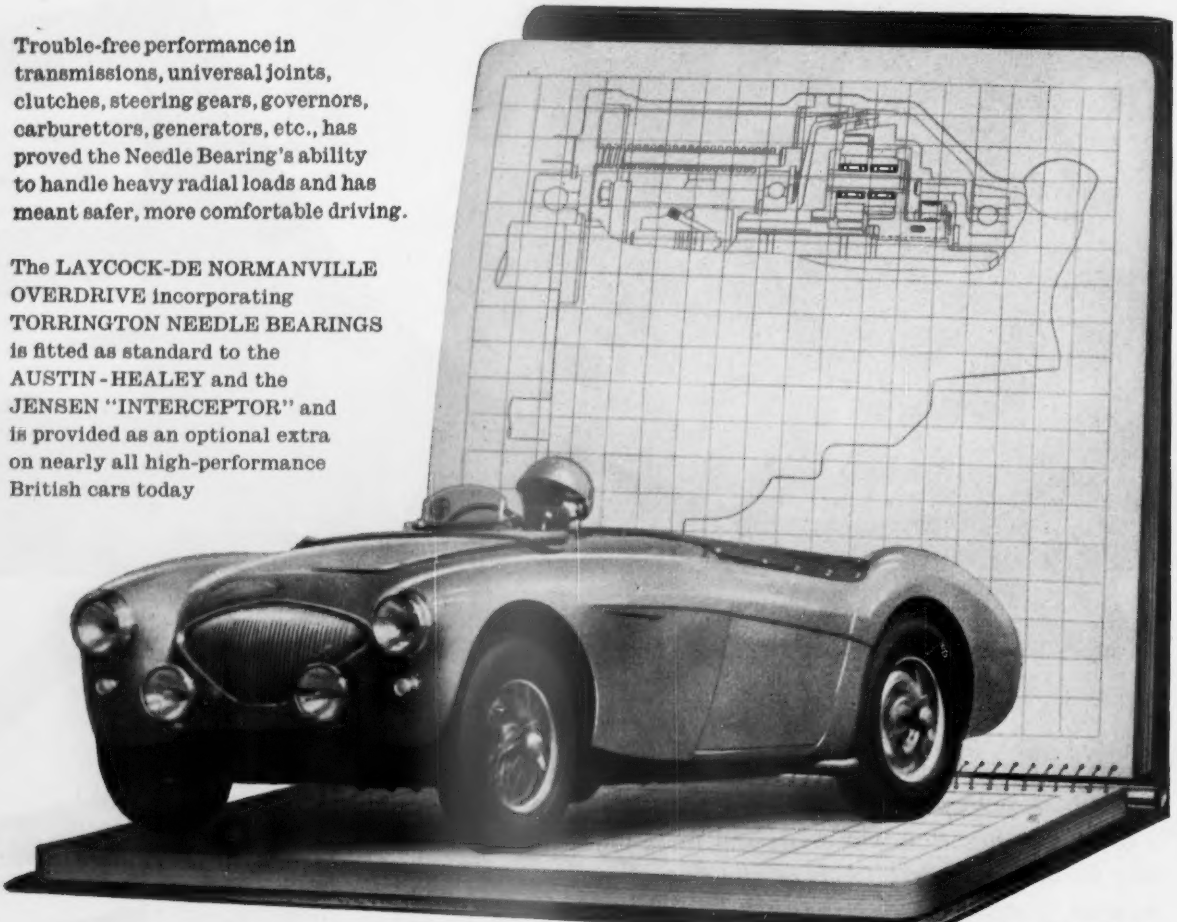
Low cost and ease of installation

are two important reasons why leading manufacturers

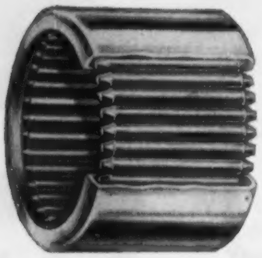
use TORRINGTON NEEDLE BEARINGS

Trouble-free performance in transmissions, universal joints, clutches, steering gears, governors, carburettors, generators, etc., has proved the Needle Bearing's ability to handle heavy radial loads and has meant safer, more comfortable driving.

The LAYCOCK-DE NORMANVILLE OVERDRIVE incorporating TORRINGTON NEEDLE BEARINGS is fitted as standard to the AUSTIN-HEALEY and the JENSEN "INTERCEPTOR" and is provided as an optional extra on nearly all high-performance British cars today



This photograph of the Austin-Healey record-breaking car is reproduced by kind permission of The Austin Motor Co. Ltd.

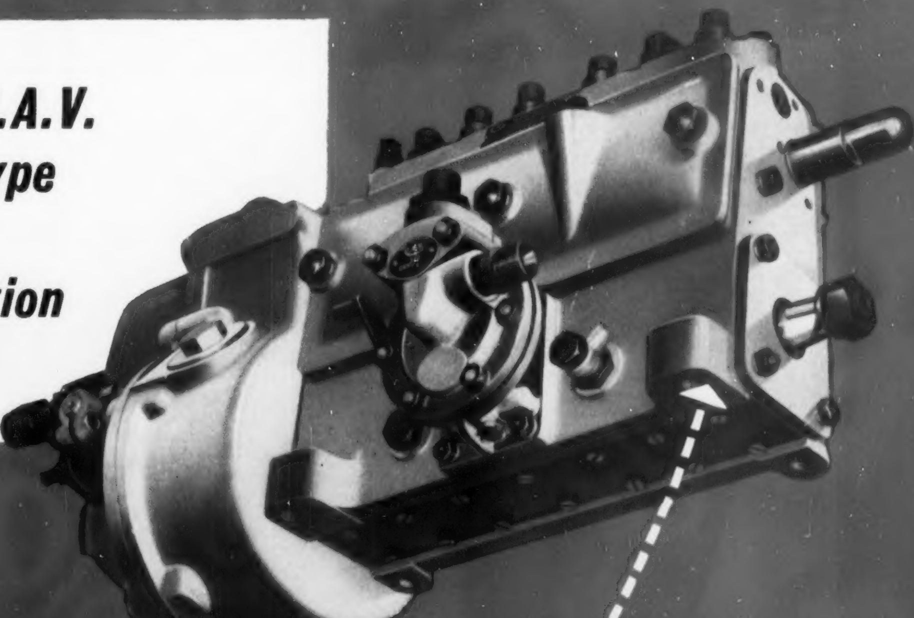


TORRINGTON NEEDLE BEARINGS

Now available from our English factory

THE TORRINGTON COMPANY LIMITED WORKS: *Torrington Avenue, Coventry* LONDON OFFICE: *7-10 Eldon Street, EC2*

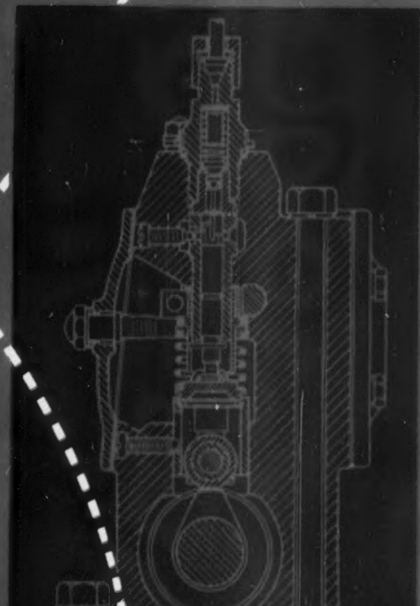
The C.A.V. 'N' Type Fuel Injection Pump



incorporates

these improved features

- Flat base mounting, with accessible through-bolt fixing, ensures positive, rigid location. Once aligned and secured, housing is free from wear; camshaft bearing life is also improved.



- Reduction in height and length of pump gives neater layout and shorter, more rigid camshaft.
- Built-in final filter protects vital elements of pump from scale, swarf, or dirt which may enter pipes during servicing of main filter.
- Delivery valve joint embodies separate high pressure (steel) and low pressure (oil-resistant rubber) joints, effectively eliminating leakage.

C.A.V.

THE LARGEST MANUFACTURERS OF FUEL INJECTION EQUIPMENT IN THE WORLD

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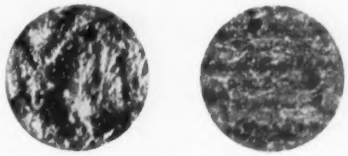
174-702

it takes a *moulded lining* to come as clean as this—

—one good reason why every CAPASCO Lining is moulded

Every trace of grease can be removed by normal degreasing methods. CAPASCO Moulded Linings are impervious to oil and grease mainly due to their uniform texture which is illustrated by the micro-photographs. Woven Linings are absorbent and should be discarded but CAPASCO can be cleaned and put back into service with the assurance of full efficiency. In addition, the other special features of CAPASCO are:— Dimensional Stability—High Mechanical and Impact Strength—Rapid 'Wet' Recovery—Extreme Resistance to Frictional Fade—Uniform Wear to 'Wafer' Thickness—Non-Abrasive to Brake Drums—Suitable for Medium and Heavy Duty Application involving High Temperatures.

WOVEN MOULDED



These micro-photographs of a Woven Lining and of a CAPASCO Moulded Lining show the very striking difference in texture. It is this homogeneous structure of a Moulded Lining which is basically responsible for the excellent overall characteristics.

CAPASCO

MOULDED BRAKE LININGS

CAPE

The Cape Asbestos Co. Ltd., 114-116 Park Street, London, W.1. *Tel:* GROsvenor 6022

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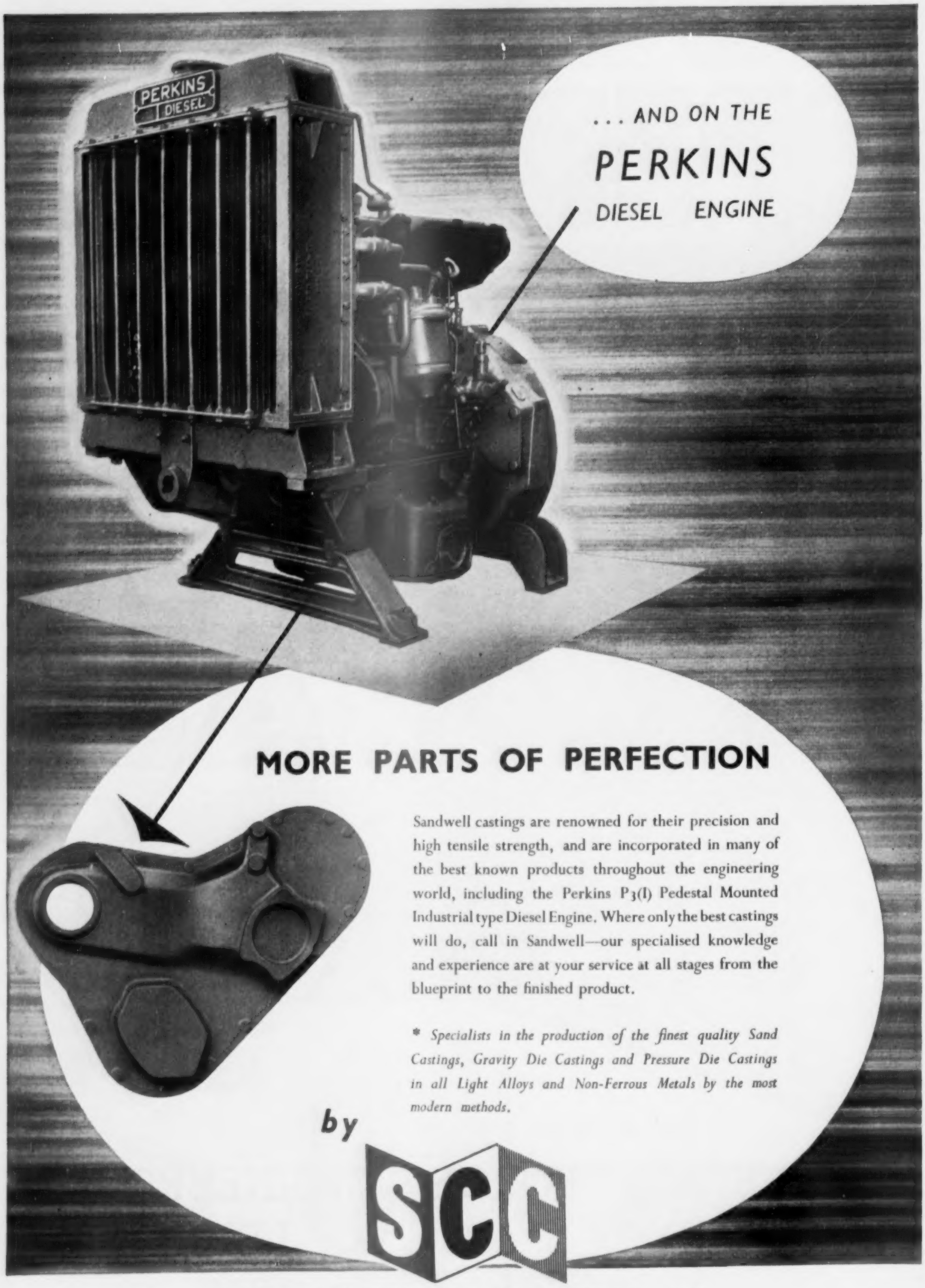
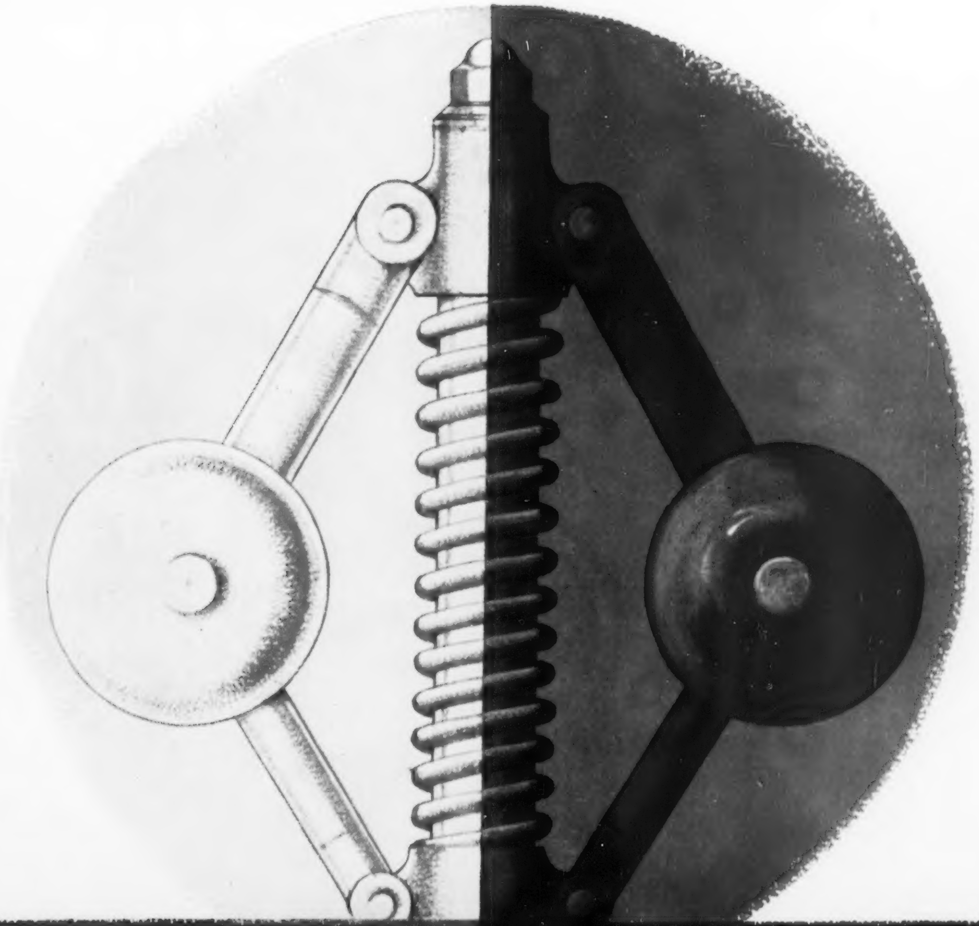


THE SANDWELL CASTING CO.

BANK STREET FOUNDRY, WEST BROMWICH   Tel: STOnecross 2231 (4 lines)   Grams: "REPCAST" WEST BROMWICH



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Evolved after many years of specialization, the Iso-Speedic governor controls speed to an extraordinary degree of accuracy, due to the elimination of static friction by rolling flybobs.

Iso-Speedic governors can be supplied which control speed within 0.3 per cent: others are available where a lower degree of accuracy is sufficient.

Servo action, exercising any desired force, can be arranged, and the services of our engineers are at your disposal.

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a Birfield Company

This Horrible Horse, said the M.D. with a pained expression on his face, is one of the worst examples of the mock-modern school of art. Note the hole where the haybag should be. Note the Desoutter Power Tool hanging inside it. Words fail me. The sculptor (foolish fellow) has got things the wrong way round and inside out. In the best modern art, which flourishes at Desoutter Hendon, the *horse* goes inside the *Power Tool*. *And* a much more useful, decorative and (if I may say so) lovable horse than that!

Desoutter tools *put power into your hands*

Desoutter Bros., Limited, The Hyde, Hendon, London, N.W.9 · Telephone: Colindale 6346 (5 lines) · Telegrams: Despnuco, Hyde, London

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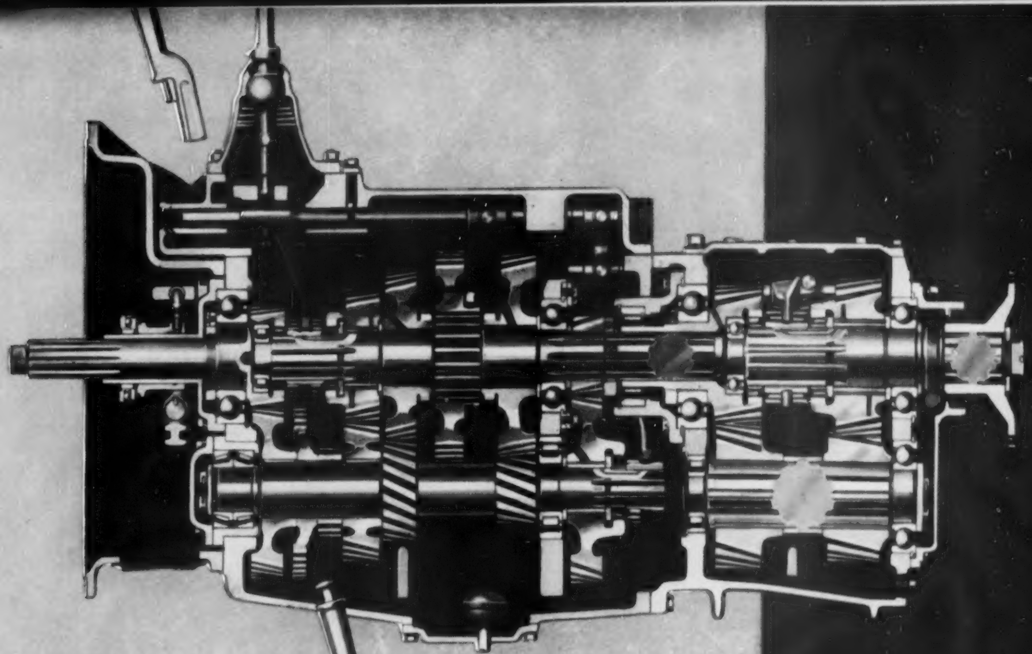
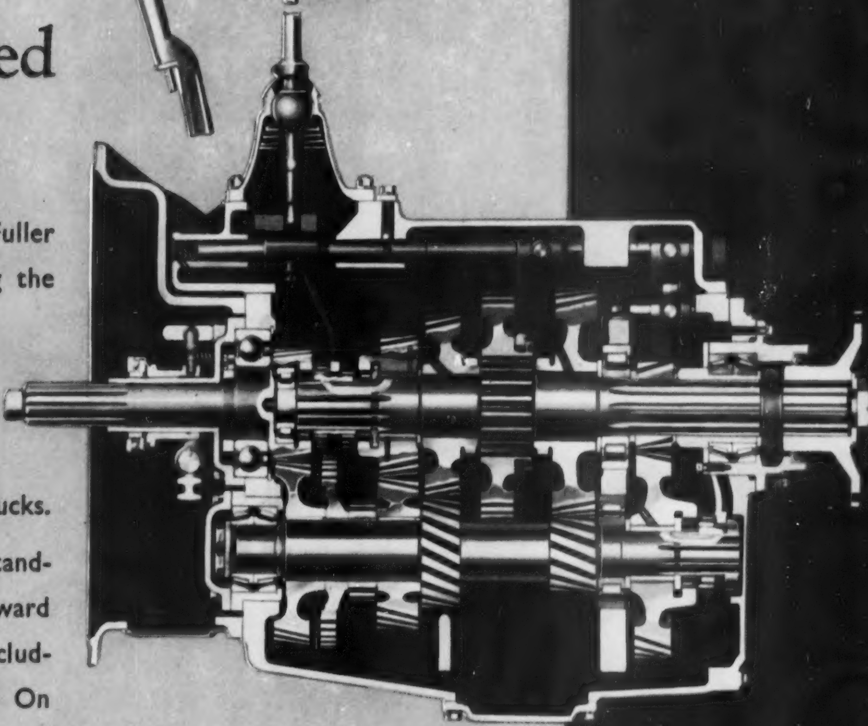


5 and 10-speed gear-boxes



The top illustration shows the Fuller 10-speed gear-box, comprising the famous five-speed box with a Fuller two-speed auxiliary box built on to it, thus providing a ten-speed box for heavy-duty operation on large trucks.

This unit is to the usual Fuller standard of high-duty, with all forward gears helical, and all changes, including reverse, by dog-clutches. On both of these boxes the gears are shot-peened and crown-shaved, to avoid stress concentration.

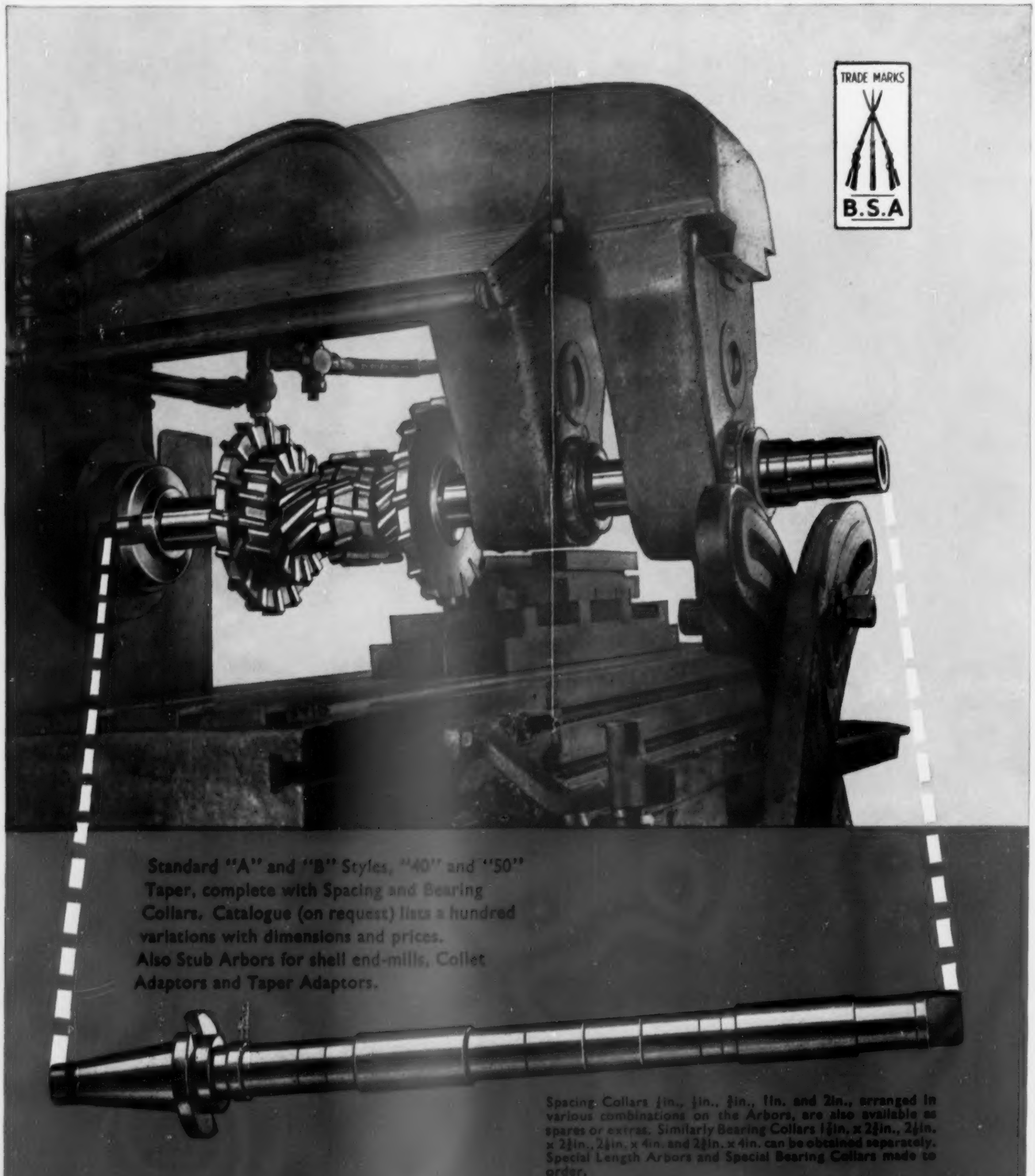
The lower illustration shows the Fuller 5-speed gear-box. Every gear is helical and engaged by dog-clutches and to reduce shaft deflection to a minimum the mainshaft is supported on three bearings, and the layshaft kept short, making one of the highest-duty gear-boxes ever produced.

Exclusive European Representatives

AUTOMOTIVE PRODUCTS COMPANY LTD.,

Brock House, Langham Street, London, W.1, England

Telephone : Langham 2527


TRADE MARKS
B.S.A
Standard "A" and "B" Styles, "40" and "50" Taper, complete with Spacing and Bearing Collars. Catalogue (on request) lists a hundred variations with dimensions and prices.
Also Stub Arbors for shell end-mills, Collet Adaptors and Taper Adaptors.
Spacing Collars $\frac{1}{8}$in., $\frac{1}{4}$in., $\frac{3}{8}$in., 1in. and 2in., arranged in various combinations on the Arbors, are also available as spares or extras. Similarly Bearing Collars $1\frac{7}{8}$in. x $2\frac{3}{8}$in., $2\frac{1}{8}$in. x $2\frac{3}{8}$in., $2\frac{1}{8}$in. x 4in. and $2\frac{3}{8}$in. x 4in. can be obtained separately. Special Length Arbors and Special Bearing Collars made to order.
B.S.A. ARBORS
B.S.A. TOOLS LIMITED BIRMINGHAM ENGLAND
CABLES "MADRICUT TELEX BIRMINGHAM"
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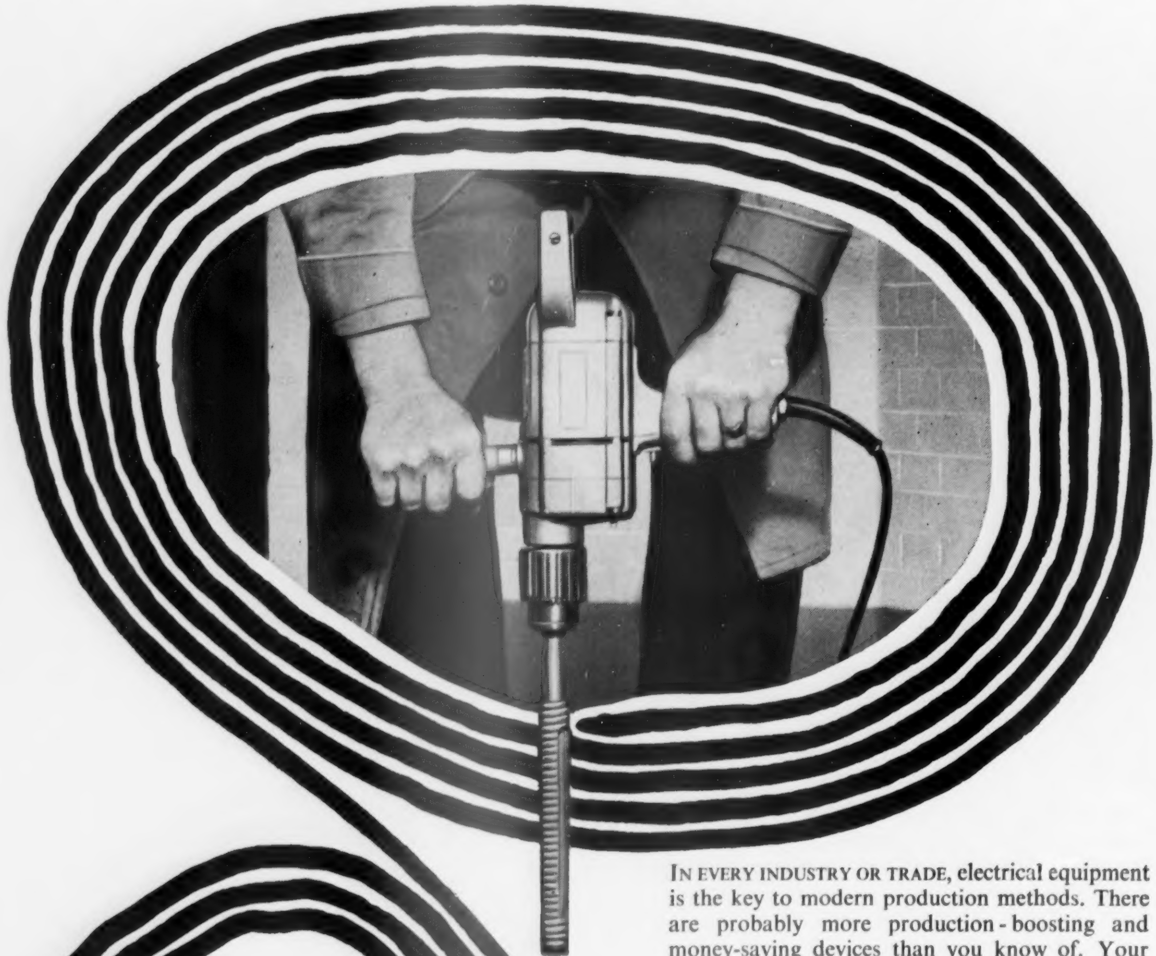
Tel. VICTORIA 2351. Teleg. "HIBOU TELEX BIRMINGHAM"
BRISTOL CARDIFF GLASGOW LEEDS LONDON MANCHESTER NOTTINGHAM

Having a hand in Productivity



Drilling for—Rag Bolts!

It sounds strange. But most of us have seen a rag bolt even if we haven't recognised it. Machinery on a concrete floor, bolted down. The bolts embedded in the concrete are rag bolts. In the old days it was a case of a man with hammer and chisel—laboriously and slowly chipping the concrete until the holes were large enough and deep enough. Now one man takes an electric drill, and drills the holes; just like that. (Productivity!) Faster? Fifty times—a hundred! But the electric drill is ONLY ONE OF THE MANY AIDS TO PRODUCTIVITY THAT ELECTRICITY CAN BRING YOU.

IN EVERY INDUSTRY OR TRADE, electrical equipment is the key to modern production methods. There are probably more production-boosting and money-saving devices than you know of. Your Electricity Board can help you and give you sound advice.

They can also make available to you, on free loan, several films on the uses of electricity in Industry—produced by the Electrical Development Association.

E.D.A. are publishing a series of books on "Electricity and Productivity". Four titles are available at the moment; they deal with Higher Production, Lighting, Materials Handling, and Resistance Heating. The books are 8/6 each (9/- post free) and the Electricity Boards (or E.D.A. themselves) can supply you.

Electricity
a Power of Good for PRODUCTIVITY

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REGD. TRADE MARK

THE GACO M.I. OIL SEAL

The Scientifically Designed Oil Seal for Rotary Shafts. A Gaco Product.

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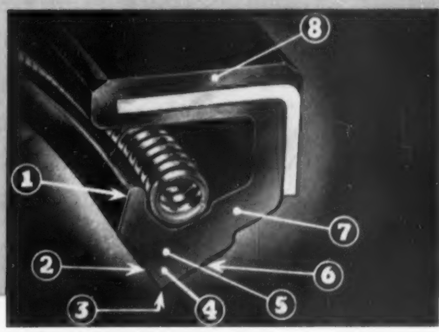
3. Knife edge Contact at Sealing Point.
4. Sealing Point stiffened against local deformation by large included angle.
5. This section stiffened to prevent deformation under load.
6. Shaft angle gives adequate clearance.
7. Flexible Web.
8. Gaco Skin affords better fluid tight fit in Housing.

"HAIRLINE" LIP CONTACT!



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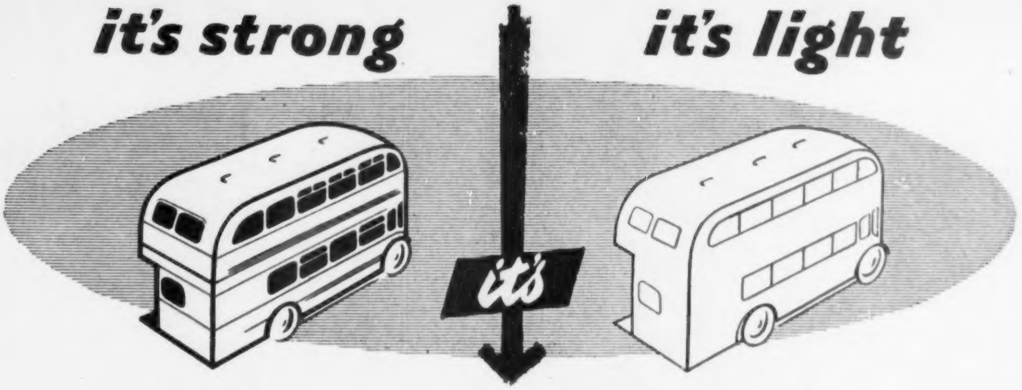
B·W·P CONTROLS, FITTINGS AND CABLES,
... the fitting answer to every control problem.
BRITISH WIRE PRODUCTS LTD., STOURPORT-ON-SEVERN, WORCS.

it's strong **it's light**



Birmabright

Engraved on 'Primag' magnesium alloy plate

Duple Motor Bodies Limited, who built this double-decker bus, made extensive use of Birmabright aluminium-magnesium alloys.

IF YOU THINK WE CAN HELP YOU, our Technical Departments will gladly advise you on the many uses of aluminium alloys.

Birmabright

Registered Trade Mark

The Pioneer Aluminium-Magnesium Alloy

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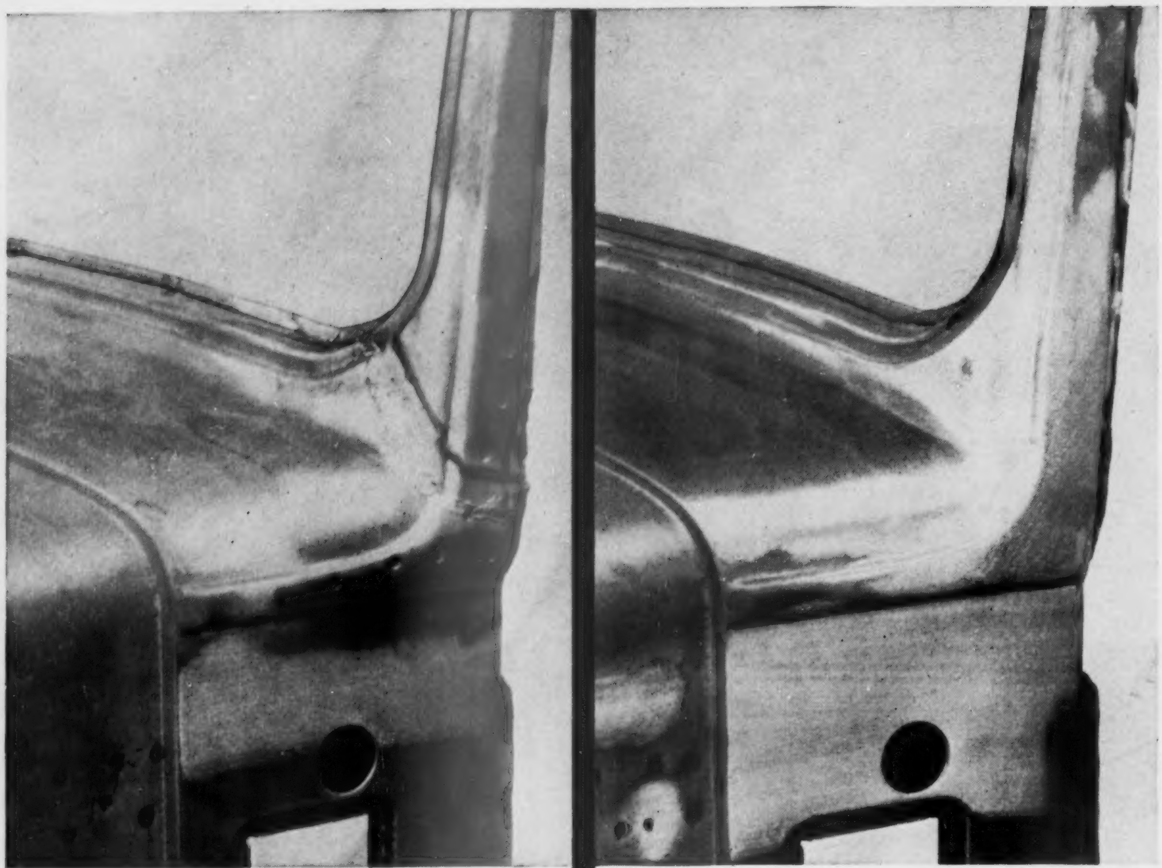
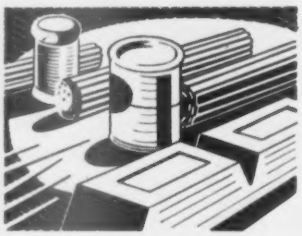


Photographs by courtesy of Pressed Steel Co. Ltd.

A *good* weld deserves — the *finest* body filling solder

Only body filling solders of guaranteed purity and consistency give the high standard of finish demanded in the automobile industry today. Enthoven solders are manufactured under rigid laboratory supervision to meet the exacting requirements of the coach builder. Enthoven Tinmans, Blowpipe, Ingot and Solid Wire Solders are supplied to B.S. 219-1949 and to customers' special specifications. Enthoven Body Solder is supplied in sticks to standard specifications or to special alloys. Entocene Solder Paint for pre-tinning on body work and for certain sweat soldering work is easy to use, clean and economical in operation. Tricene Soldering Fluid for use with all soft solders gives safe, vigorous fluxing without corrosive residue.



Our technical advisers and laboratory staff are available for consultation. Technical data, descriptive literature and samples will be gladly sent on request.

ENTHOVEN SOLDER PRODUCTS

ENTHOVEN SOLDERS LIMITED, 89, UPPER THAMES STREET, LONDON, E.C.4. Telephone: MANsion House 4533. Telegrams: ENTHOVEN PHONE LONDON

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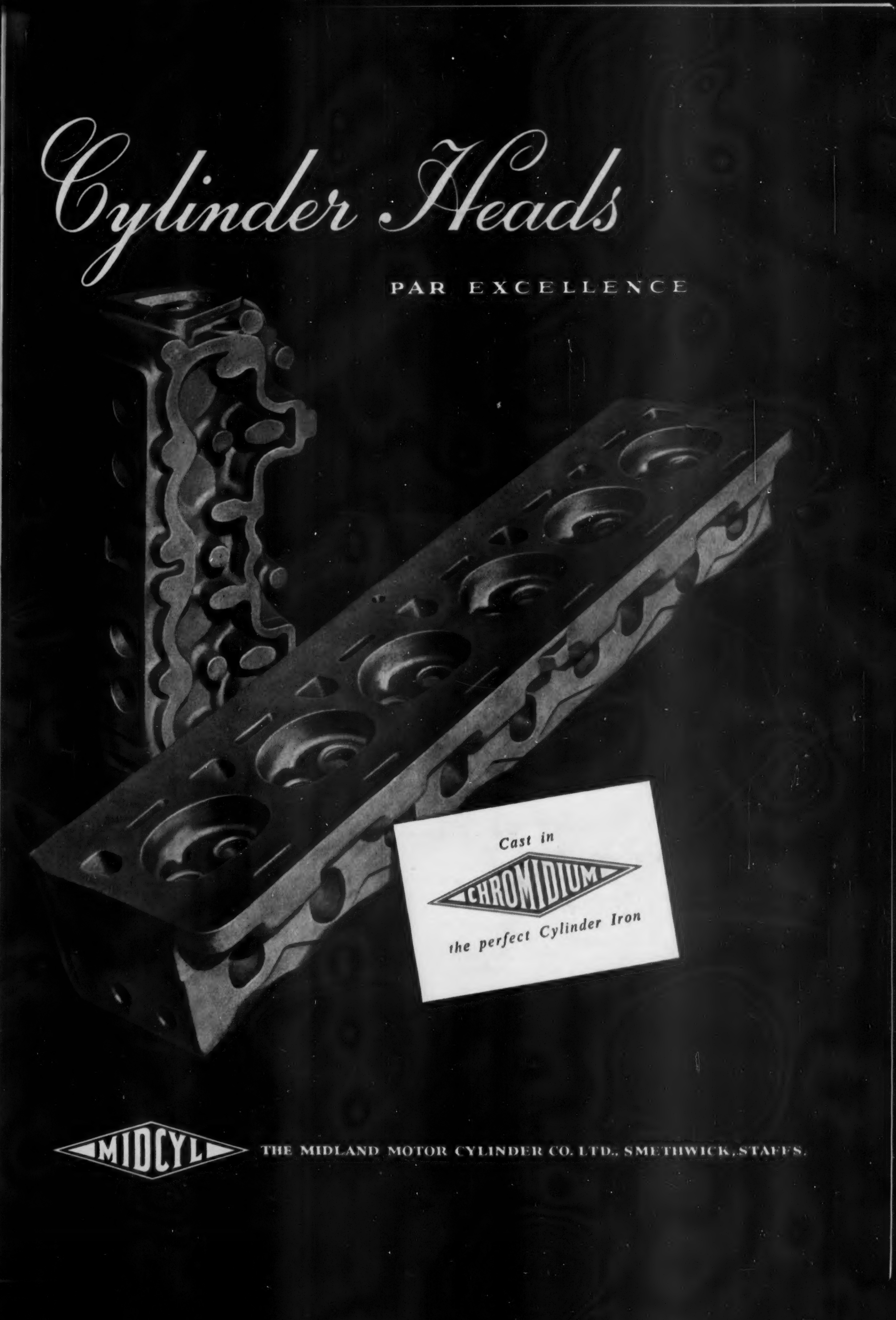
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PAR EXCELLENCE
Cast in
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CP22

Hicycle TOOLS IN THE SERVICE OF THE AUTOMOBILE INDUSTRY

Hicycle tools should not be confused with ordinary 50-cycle electric tools. Operating instead on 200 cycles they develop a motor speed which is sustained under all operating loads. This means measurably more work in a shorter period, and although possessing the toughness of air tools their operating costs are considerably lower. Moreover, Hicycle tools are safe, only 125 volts or 72 volts to earth.

Hicycle is accepted as THE modern production system wherever drilling, reaming, tapping, nut-running, studsetting and grinding operations are carried out on any scale. In fact, Hicycle should be investigated wherever there are more than two or three power tools in use.

Automobile construction is one of the many industries in which Hicycle has proved its power to increase output and lower costs. Write for publication S.P.354 as a first step to increasing the efficiency of your production.

FOR THE RIGHT APPROACH... THE RIGHT EQUIPMENT

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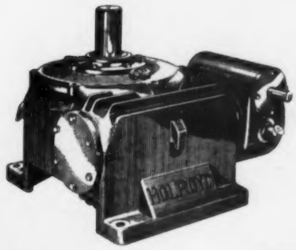
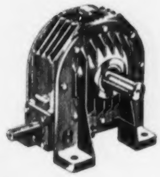
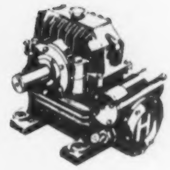
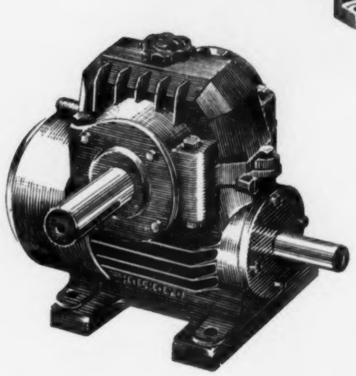
the things they make at Holroyd's





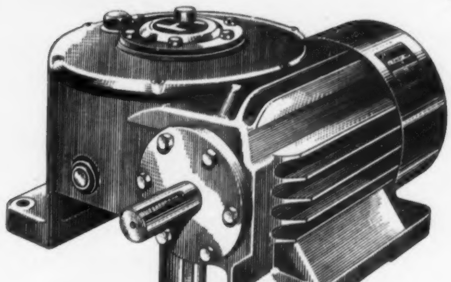




THEY'VE WRITTEN A BOOK ABOUT THEM

Holroyd's have written a book about their Worm Gear Reduction Units. It gives full details on their Underdriven, Overdriven and Vertical Type Units — selection and service, horsepower and torque, dimensions, efficiencies, lubrication and maintenance — all the facts a worm gear user needs. They'll be glad to send you a copy, together with information on the other three kinds of Worm Unit shown above, (the 'F' and double reduction types).

Their address is John Holroyd & Co., Ltd., Milnrow, Lancs.



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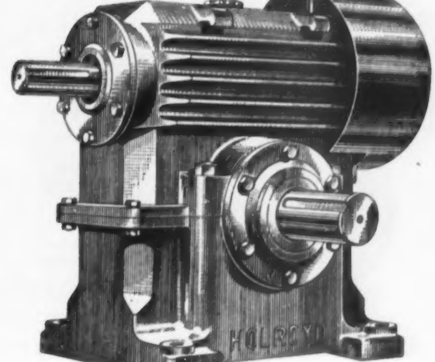

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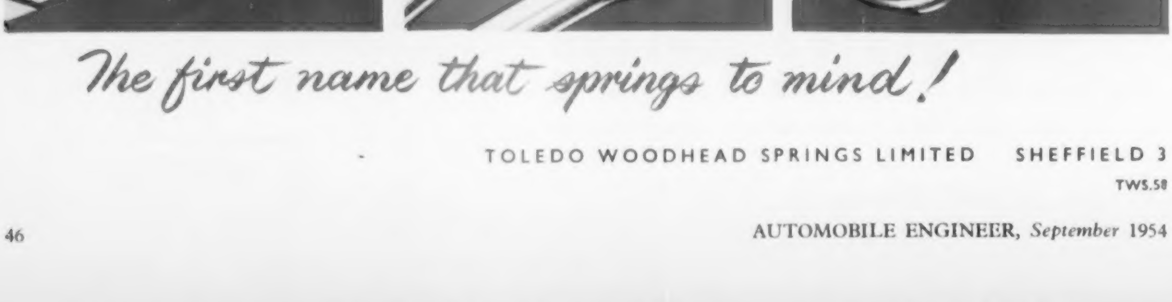

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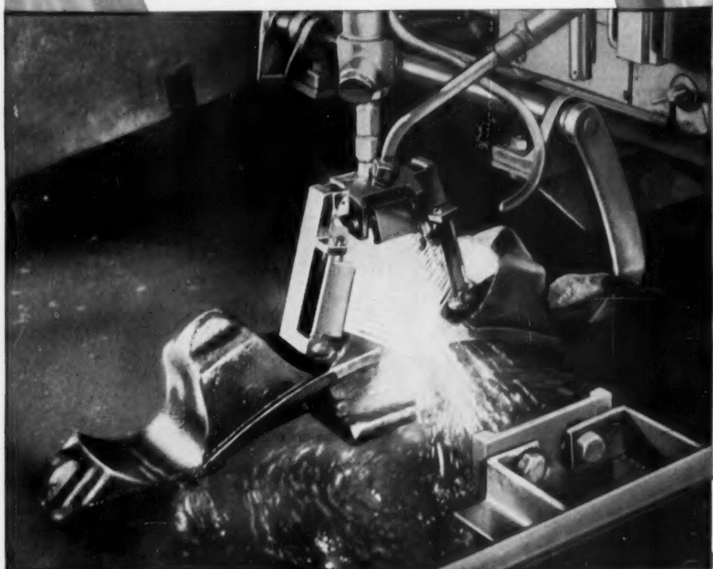

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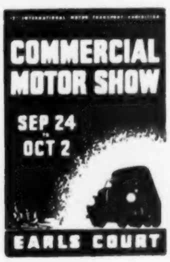

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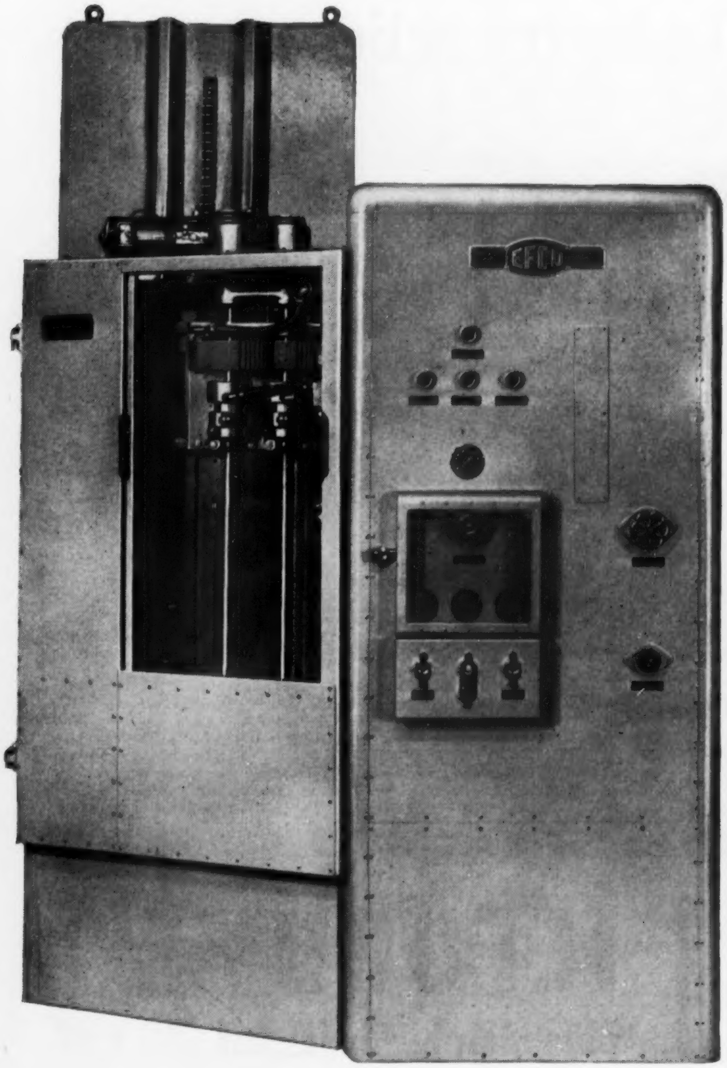

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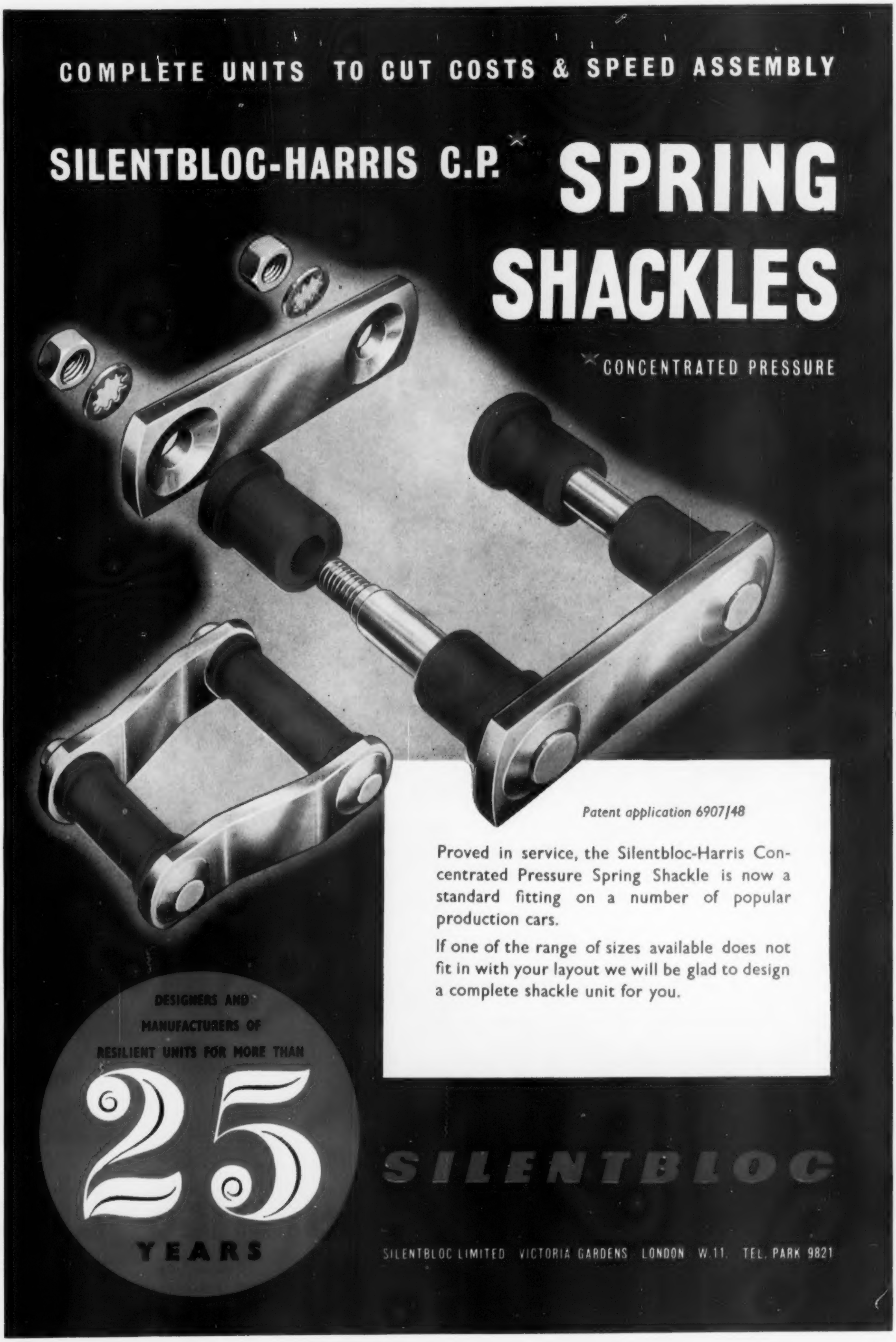
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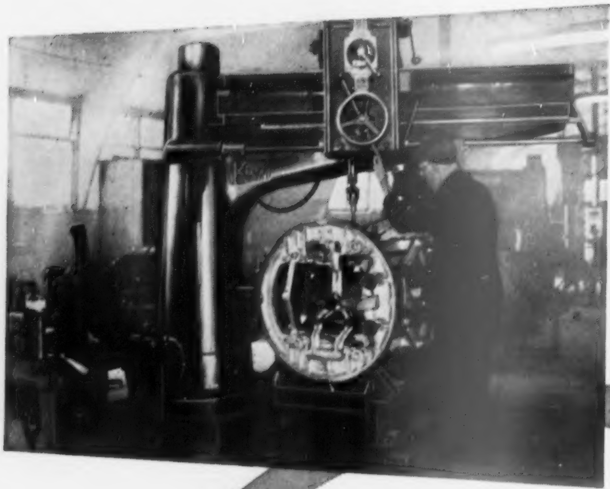

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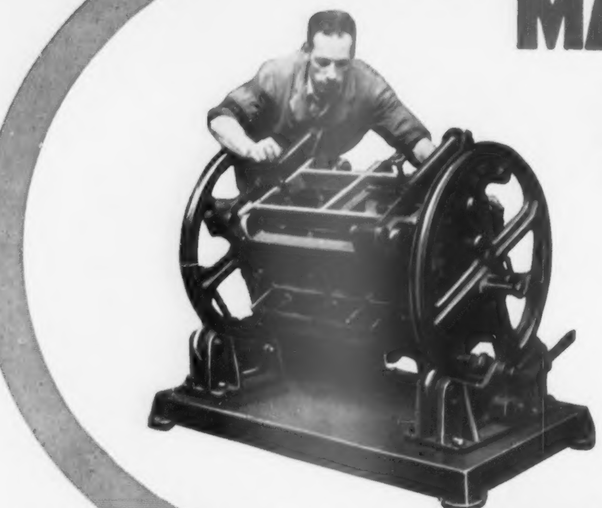

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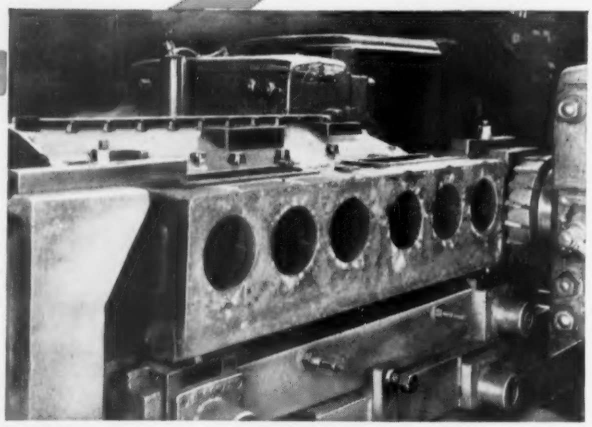

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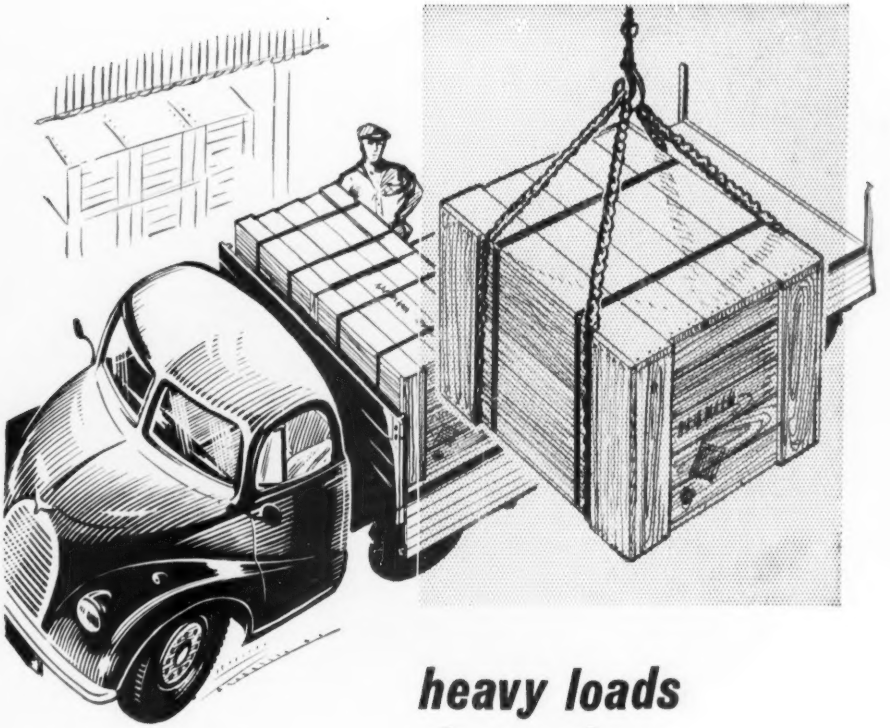

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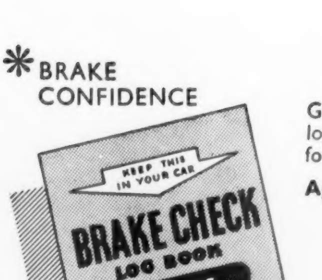

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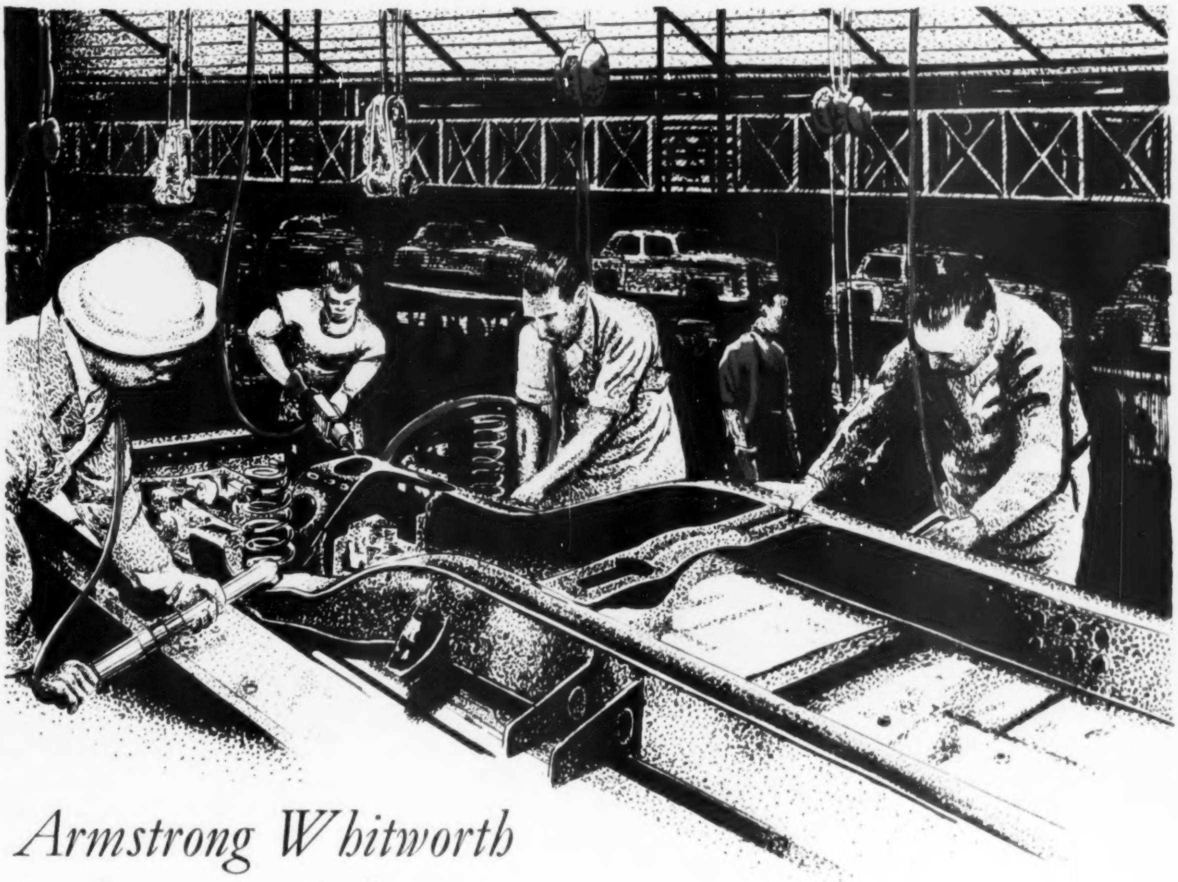

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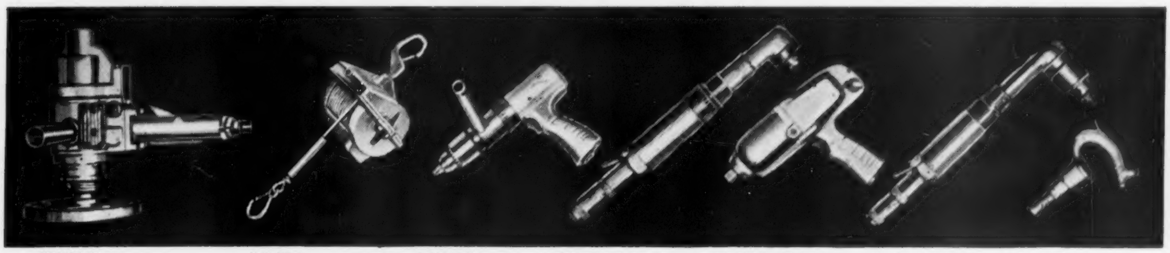

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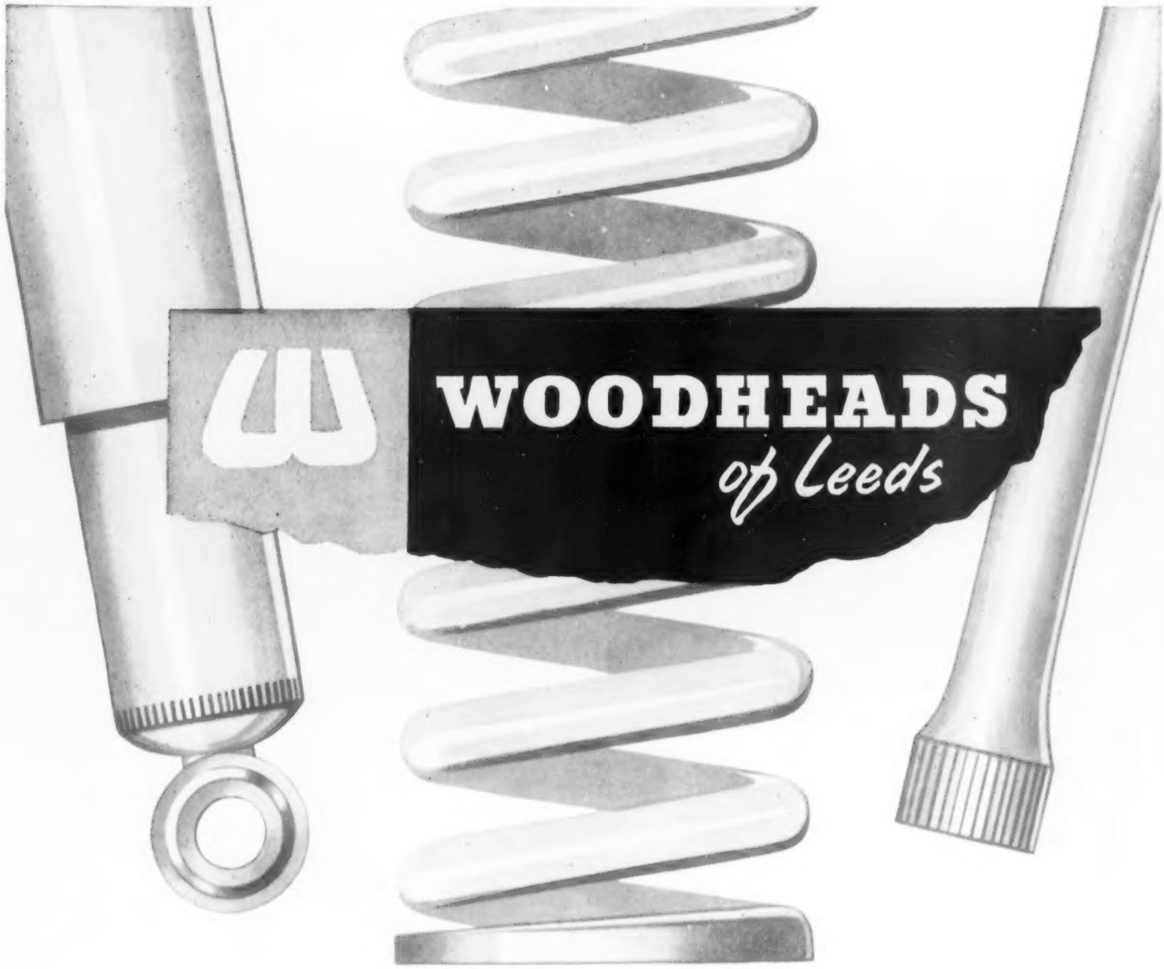
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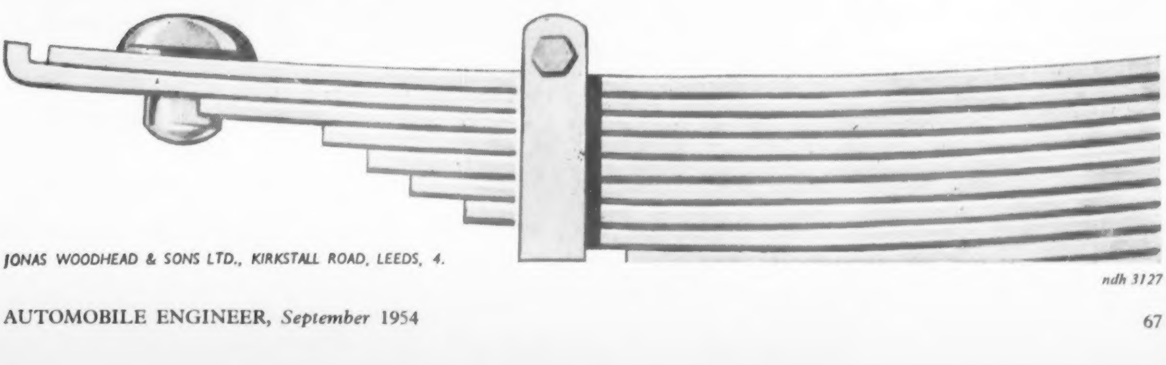

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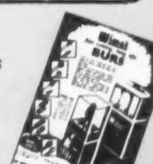

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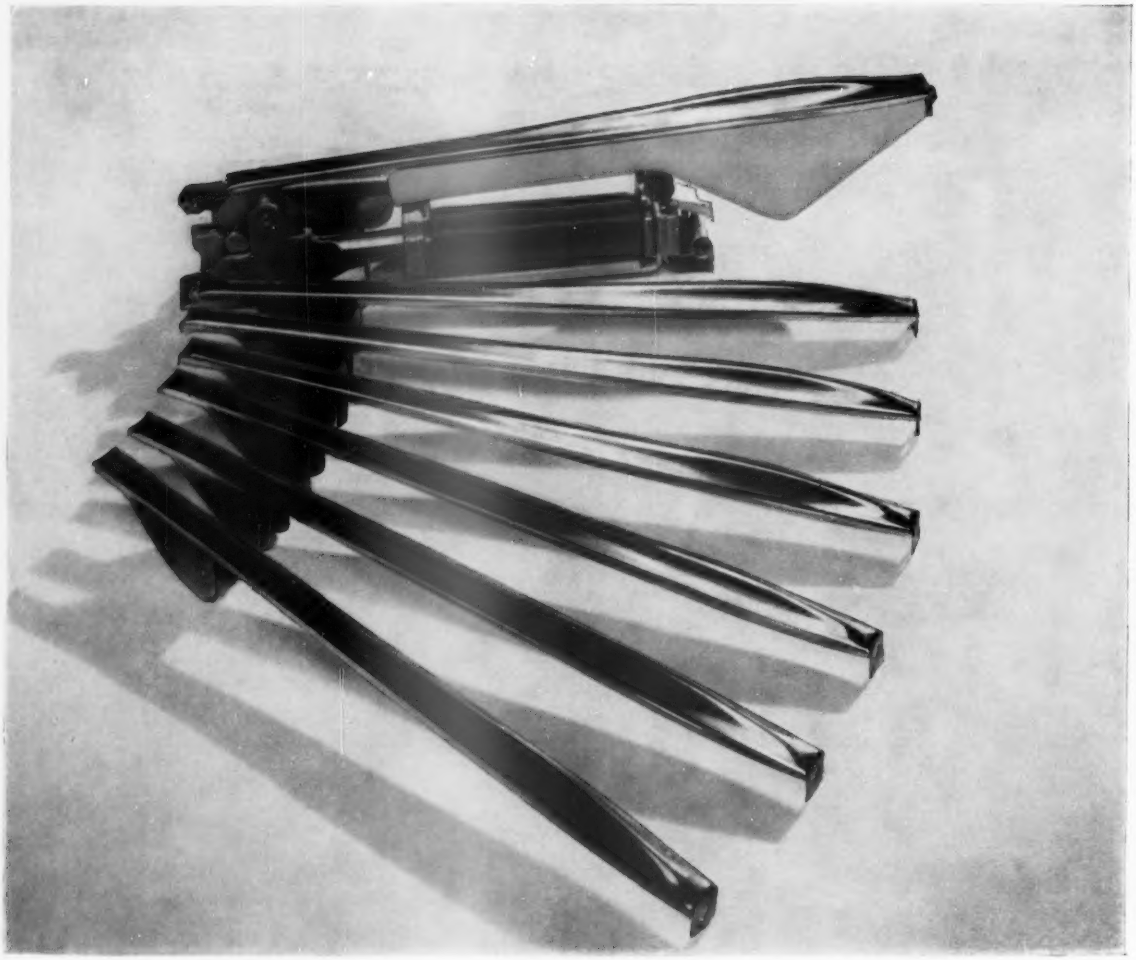

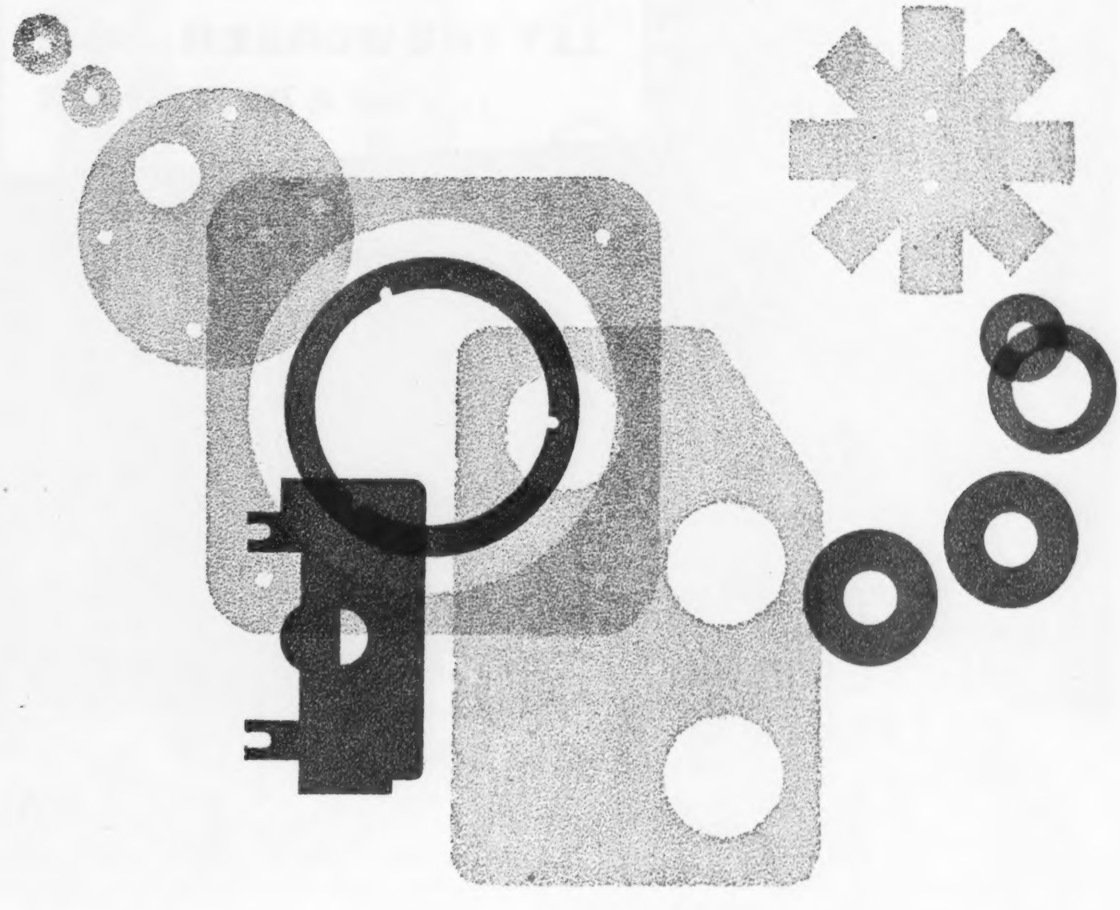

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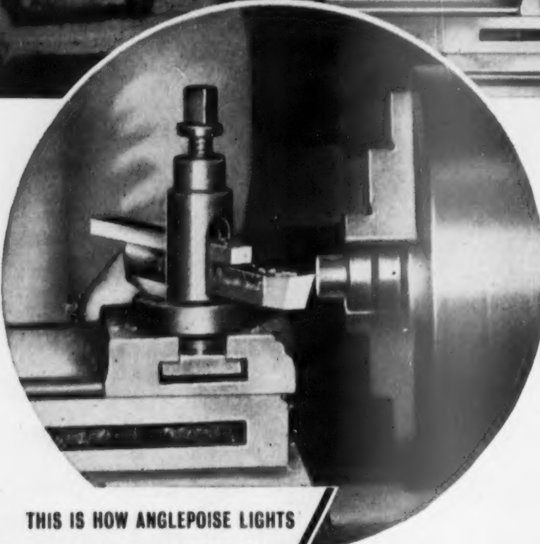

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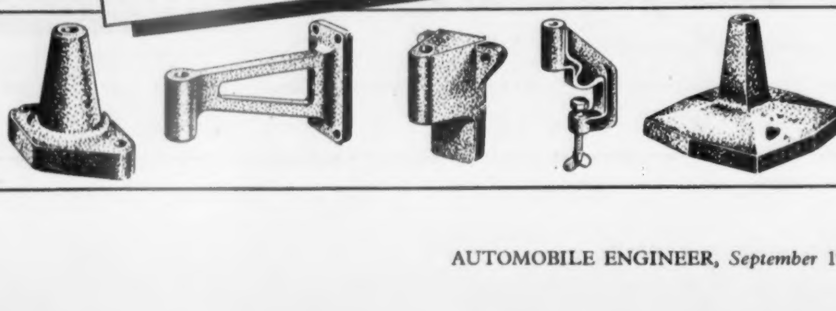

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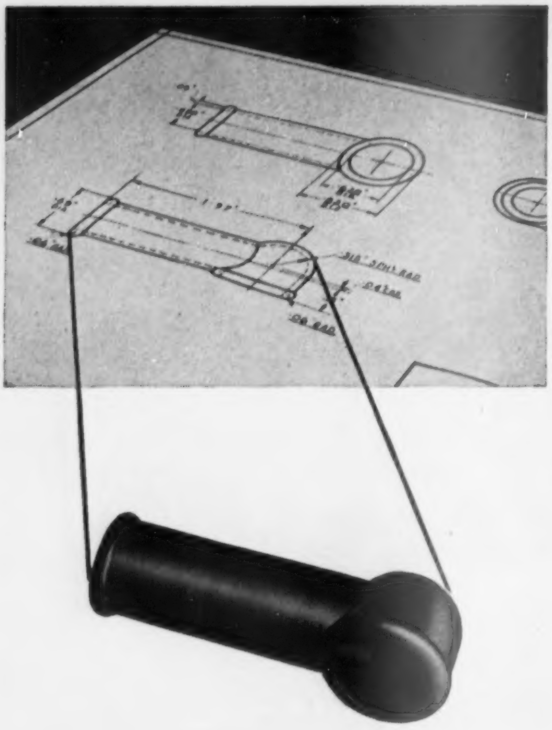

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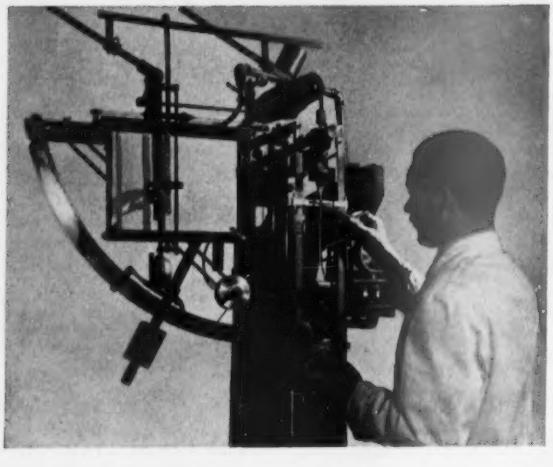

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Fuel Economy

BECAUSE of price differentials, fuel economy is a matter of much greater moment in this country and Western Europe than it is in the United States of America. Since the war, British and Continental manufacturers of medium and low price cars have laid great stress on low fuel consumption, whereas American manufacturers have not laid anything like the same stress on this aspect of vehicle usage. As a result there is a tendency to think that American cars are extravagant on fuel. That this is a mistaken idea, is demonstrated by a comparison of the Mobilgas Economy Runs for 1953 and 1954.

Direct comparisons in miles per gallon for the two years is not possible, since different routes were covered. The difference was in favour of the 1953 engines, since for 1954 the heavy traffic mileage was doubled, and in addition part of the route called for the use of chains for driving through snow. There were, therefore, reasons for expecting that the 1954 results would not be as good as those for 1953. Actually, despite the more onerous conditions, the results for cars without automatic transmission showed that whereas the average miles per gallon in 1953 was 23·60, in 1954 it rose to 24·24; for cars with automatic transmissions it remained constant at 19·81.

Power output

The average horse power developed by the engines of cars with automatic transmission increased from 151 in 1953 to 164 in 1954, and for this group the compression ratio increased from 7·43 to 7·48:1. Despite the increased power and the more onerous conditions, the average m.p.g. for this group was the same in 1954 as in 1953. For cars without automatic transmission the average engine output increased from 118 to 129 h.p. with average compression ratios increased from 7·15 to 7·37:1. This suggests that with the correct grade of fuel, an increase in compression ratio will lead to improved fuel economy.

Perhaps the best conception of the efficiency of these 1954 American engines may be gained from a more detailed study of the figures for three Studebaker cars, each of which won first place in its class. In the class for low-price cars without automatic transmissions a Studebaker Champion Custom averaged 29·58 miles to the gallon for the 1,335 miles of the run. This is remarkably good for a six-cylinder engine of 2,770 cm^3 displacement, with a 7·50:1 compression ratio, a maximum b.h.p. of 85 at 4,000 r.p.m., and a maximum torque of 138 lb-ft at 2,400 r.p.m.

Comparable figures were also obtained on a Studebaker Land Cruiser, without automatic transmission, which gave an average of 28·10 m.p.g. This is remarkable for an eight-cylinder engine of 3,800 cm^3 displacement. The compression ratio for this power unit is 7·50:1, the maximum b.h.p. 127 at 4,000 r.p.m., and the maximum torque 202 lb-ft at 2,000 r.p.m. When regard is given to their size, both these engines must be considered very economical.

Automatic transmission

The effect of fitting an automatic transmission is clearly shown by the figures for a Studebaker Land Cruiser with automatic transmission. Although this vehicle was easily the best in its class for fuel economy, it gave only 24·57 miles per gallon against the 28·10 miles per gallon for a similar vehicle without automatic transmission. To say the least, this suggests that relatively few motorists in this country and Western Europe will consider automatic transmission worth while, since it will entail an increase in the order of 14 per cent for fuel charges in addition to a fairly considerable increase in the first cost of the vehicle.

Acceptance Tests

MAINTENANCE of product quality demands that all bought-out materials and components must comply to a specification of one kind or another. Naturally, this entails the formulation of acceptance standards, and it is fortunate that in most cases the necessary tests can follow only one set pattern. For example, a metal must conform to a certain chemical analysis and have certain mechanical and physical properties. The supplier may consider that the chemical specification is too strict, but once agreement is reached on specification, there cannot be any doubt as to the validity of the acceptance tests, since they follow a standardized procedure.

There are, however, important materials and components, whose suppliers may have good reasons for contending that the user's acceptance tests are incorrect, or even valueless, for assessing the functional fitness of the product for its designed purpose. In these cases the supplier's objection to the test is not that they are too stringent, but rather that the test procedure is basically wrong. As a result, it is claimed, assessment of quality may be made on a basis that has no real meaning, and functionally satisfactory material may be rejected.

Materials and components supplied to automobile manufacturers come from reputable organizations, which

are proud of their reputations and take great pains to maintain the quality of their products. These suppliers would not knowingly supply faulty or unsuitable material, and there is no doubt that automobile manufacturers should give most serious consideration to any acceptance tests proposed by the supplier, who, even if only from self-interest, is as anxious as the vehicle manufacturer to ensure that his product gives satisfaction.

This question is particularly acute where very specialized items are concerned. The producers of these items have a fund of basic knowledge concerning their products, which the user cannot hope to equal. For optimum economy and efficiency the greatest possible use should be made of this specialized knowledge. Therefore, the logical procedure is for the automobile manufacturer to specify the function to be performed by the material or component. leaving the supplier to decide how the specified requirements shall best be met. From this it follows that the supplying organization should also formulate the acceptance tests. This will give assurance that the desired qualities are correctly assessed, and will be to the benefit of both the supplier and the vehicle manufacturer.

All-Round Visibility

A FEW years ago, the rapid increase in popularity of the hard top type of passenger car in the United States of America took many people by surprise. Possibly the reason for this was that the hard top is a difficult subject for the stylist, and even now the general lines of the roofs of these vehicles in some instances scarcely harmonize with those of the rest of their bodies. However, the advantage of exceptionally good visibility to the rear apparently outweighs any disadvantages so far as styling is concerned.

This is a positive indication that further improvements in all-round visibility would be a strong attraction to potential customers. That there is room for improvement is apparent from the fact that rear view mirrors additional to those supplied with vehicles are to be seen fitted on many new models now on the roads. Blind spots at the rear quarters are frequently a cause of embarrassment and sometimes of accidents. The same can be said of windscreen pillars and even of the door centre pillars in four-door saloons. In fast moving traffic, it is essential to be able to see at a glance whether the road is clear at junctions and cross roads. The centre pillars, as well as the windscreen pillars, often prevent this.

Distortion problems with curved windscreens have received considerable publicity and it is unlikely that any manufacturers will be caught in this pitfall. Nevertheless, it is a feature that needs to be studied if the wrap-round type of screen, currently popular in America, is adopted in this country. It does not necessarily follow that if a wrap-round screen is adopted visibility will be improved. The position of the windscreen pillar is governed, of course, more by considerations of ease of access to the front seats than by styling. Therefore, if the pillar is moved further to the rear the tendency will be for the front seat also to be moved back, thus placing it in the same position relative to the driver as it would be with a more conventional design.

It would appear that the only satisfactory way to improve on the existing arrangement is to reduce the size of the pillars or, better still, to eliminate them altogether. The centre pillar in the door aperture in many designs adds but little to the stiffness of the vehicle, and in some models it has been eliminated altogether. Two-door vehicles are relatively simple to design without a centre pillar and this arrangement is not impossible in four-door models.

The fact that convertible and drop head types of car are satisfactory so far as strength and stiffness are concerned, is an indication that the roof panel is not an indispensable structural component. Admittedly, the open models have windscreen pillars but these are in fact what their name implies: that is, their sole purpose is to support the screen. When the screen has the additional support of the roof panel, it should be possible to fit pillars of much more slender cross-section. Probably an open joint would be desirable at the top of each pillar because bending deflections of the vehicle might otherwise lead to cracking at that point.

CONTENTS

POPPET VALVES, GUIDES AND SEATS

Part I. A Survey of Valve Materials and General Design Features

THE valve problems that confront engine designers are probably more difficult than those associated with any other component. This is because not only are the combinations of loading, temperature and corrosion severe, but also many of the operating conditions to which the valves in any particular engine will be subject are unpredictable and can only be determined during development. Moreover, some of the design requirements are conflicting and call for a careful compromise.

Since under extreme conditions valves may operate at temperatures of more than 800 deg C, they can hardly be expected to last indefinitely. Nevertheless, under normal operating conditions the valves in private car engines should last for 20,000 miles. Commercial vehicle engines, of course, are serviced at more regular intervals. Reconditioned cylinder head assemblies may be fitted, for instance, every 20,000 miles. In these circumstances, there is no objection to new valves being fitted during a normal overhaul period, that is, after about 75,000 to 100,000 miles, when the engine is dismantled for rebore and the fitment of new pistons and rings. This procedure should only be adopted if it is more economical than to fit initially valves of a quality that will last the life of the engine.

Designing for a specific life is not easy. Valve failures are generally caused by thermal, mechanical or corrosion fatigue, either singly or in combination, and it is well known that when fatigue failures at any given load are plotted against the number of reversals of load or engine running time, the results are always widely scattered. Moreover, manufacturers have to produce engines for use in all parts of the world and under greatly differing operating conditions; this leads to even greater variations in the expectancy of life.

This indicates that the quality required of valves for export to one country, or for one set of operating conditions, is not necessarily suitable for other countries and conditions. Unfortunately, because of the intense competition in many markets of the world, there is a tendency for customers to demand the cheapest product without realizing that by so doing they may be getting inferior materials. Therefore, it is essential that customers should be educated to accept the fact that in ordering valves for replacement or specifying them for initial fitment, they must take local conditions into consideration.

Operating conditions

Mechanically, valves are subject to relatively heavy loading. Modern developments in cam design have done much to alleviate this, but accelerations are still in the order of 100-400g, and in certain circumstances, notably if the tappet clearances are incorrect, the acceleration may be appreciably in excess of these figures. Moreover, the tendency towards lower loading, as a result of better cam profiles, is in some degree offset by other trends.

Higher speeds, larger compression ratios and increased ratings of modern engines as compared with earlier ones have tended to lead to higher valve temperatures, so creep, fatigue and corrosion difficulties are continually increasing. The detrimental effects of higher compression ratios are to some extent offset by the cooler exhaust obtained because of the increased expansion ratio, but other factors that adversely influence valve performance are introduced. It is generally accepted that in orthodox poppet valve engines, some leakage inevitably takes place past the valves. Higher compression ratios increase the amount of blow-by, and therefore valve temperatures. An engine that is satisfactory at, for instance, 7:1 compression ratio may be marginal at 7·5:1 and definitely unacceptable at 8:1 compression ratios, unless the design is improved and better materials employed. If inferior grades of fuel are used in engines of high compression ratio, detonation may cause increased valve temperatures. The demand for fuels of high octane value has resulted in some instances in larger proportions of tetra-ethyl-lead being used; this has further added to the corrosion problems.

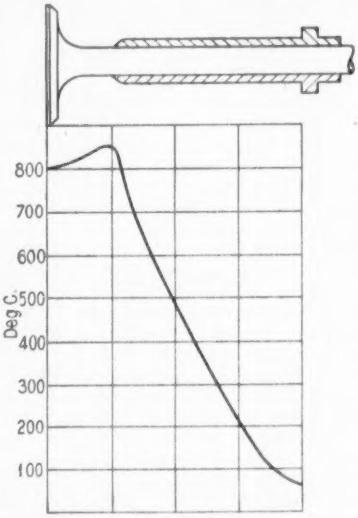


Fig. 1. A typical temperature gradient diagram for an exhaust valve

Valve temperatures experienced vary widely as between different engine designs, valve designs, fuels used and operating conditions. Therefore, the following range for various categories of engines can only be an approximate indication of maximum temperatures likely to be developed in exhaust valves. In commercial vehicle diesel engines with solid valves, the maximum temperature may be about 780 deg C. In petrol engines for heavy commercial vehicles, the maximum temperature may be as high as 800-840 deg C; exhaust valve temperatures in petrol engines for light trucks are in many instances about 720 deg C; and in private cars they are usually about 650 deg C. Nearly all aero engine exhaust valves are sodium cooled and generally operate at about 650-750 deg C. Heat flow from the valve takes place through two paths, one through the seat and the other through the guide, so the highest temperatures are usually found in the neck, or the junction between the head and the stem, Fig. 1.

Valve and seat temperatures may be determined by making the components of a steel, the hardness of which changes with the temperature of operation. They are assembled into an engine, which is then run at steady conditions for about 50 hours. After this, the components are removed, sectioned if necessary, and hardness tested at various points. These hardness figures may be compared against known standards to determine at what temperatures the particular part was operating.

In an engine that has been in operation for some time, excessive running temperatures may be indicated by an absence of deposits on the exhaust valve heads. When investigating the causes of over-heating during service, it should be borne in mind that pre-ignition frequently leads to this trouble. The resulting increase of valve temperature may cause the valve stem to expand and the tappet clearance to be taken up. This causes blow-by to occur and leads to even higher temperatures. Another type of failure sometimes caused by over-heating is the cupping of valve heads. It can be detected by the fact that tappet clearance frequently has to be adjusted. If the reduction in clearance is not

TABLE I. DATA CONCERNING THE BRITISH STANDARD STEELS GIVEN HERE AND IN TABLE II BUT NOT QUOTED IN B.S. 970 ARE ONLY APPROXIMATE. DETAILS OF THE PROPRIETARY MATERIALS HAVE BEEN SUPPLIED BY THE APPROPRIATE MANUFACTURERS

Make and Equivalent B.S. Spec.	Types of Valve	Advantages	Disadvantages	Composition, per cent	Heat Treatment		Thermal Expansion $\times 10^6$ for Temperature Range of 20–600 deg C
					Quenched at deg C	Tempered at deg C	
En 51	Inlet	Easy to machine and process	Low creep resistance.	C 0·25–0·35 Mn 0·35–0·75 Cr 0–0·30 Si 0·10–0·35 Ni 2·75–3·5 S and P 0–0·05	830–850 in oil	550–650	13·6
En 52 Silcrome type	Inlet, and diesel and low-rated petrol engine exhaust	High resistance to scaling. Can be hardened.	Lower creep resistance than En 53	C 0·40–0·50 Mn 0·30–0·60 Cr 7·50–9·50 Si 3·00–3·75 Ni 0–0·50 S and P 0–0·4	1,000–1,050 in oil or air	650–850	13·4
En 53	Inlet and exhaust	Good creep resistance up to 700 deg C	Low scaling resistance above 700 deg C	C 0·55–0·65 Mn 0·30–0·60 Cr 5·75–6·75 Si 1·40–1·70 Ni 0–0·50 S and P 0–0·5	950–1,000 in oil	720–800	13·6
En 54 Austenitic	Exhaust on highly-rated engines, mainly petrol	Good oxidation resistance and strength at high temperatures		C 0·35–0·50 Mn 0–1·50 Cr 12·00–16·00 S and P 0–0·05 Si 1·00–2·50 Ni 10·00 min W 2·00–4·00	950–1,020 in oil, water or air	740 in air	18·9
En 59 XB type	Exhaust	High resistance to lead corrosion. Can be hardened		C 0·74–0·84 Mn 0·20–0·60 Cr 19·00–20·50 Si 1·75–2·25 Ni 1·15–1·65 S and P 0–0·03	1,050–1,080 in oil or air	700–750	12·3
Jessop E1A En 51	Inlet. Occasionally low duty exhaust	Readily machined and processed	Low corrosion resistance and hot strength	C 0·30 Mn 0·70 Si 0·25 Ni 3·25	850 in oil	630 in air	13·6
Jessop G2A S.T.A.5 V26, D.T.D.49B En 54	High duty exhaust	Highly resistant to lead attack, good corrosion resistance, strength and hardness at high temperatures	High coefficient of expansion. Must be hard faced at tappet end	C 0·42 Mn 0·70 Cr 13·0 Si 1·30 Ni 13·0 W 2·50 Nb 0·2	Normalize 950		18·9
Jessop G32	High duty exhaust in racing engines	Exceptional creep and fatigue strength at 750-800 deg C. High proof stress at room temperature	Expensive	C 0·30 Ni 12·5 V 2·80 Si 0·50 Cr 19·0 Nb 1·30 Mn 0·80 Co 45·0 Mo 2·0	Solution treatment 1,280 oil quench	Age 46 hr at 750	16·4
Jessop H3 D.T.D. 311 En 53	Inlet and exhaust	Hardenable	Unsuitable for high temperature applications	C 0·6 Mn 0·5 Si 1·55 Cr 5·8	980 in air	780 in water or oil	13·6
Jessop H18 S.T.A.5 V24, D.T.D.13B En 52	Inlet and exhaust	Relatively inexpensive. Stem can be hardened. Low coefficient of expansion	Unsuitable for high duty applications	C 0·45 Mn 0·40 Si 3·50 Cr 9·00	1,050 in oil	850 in water or oil	13·2
Jessop H29 En 59 XB type	Inlet and exhaust	Good resistance to lead attack. Hardenable. Low coefficient of expansion		C 0·80 Mn 0·50 Si 2·00 Ni 1·50 Cr 19·5	1,050 in oil or air	740 in air	12·3
Jessop H38	Inlet and exhaust	Hardenable	Unsuitable for high duty applications	C 0·50 Mn 0·50 Si 3·00 Cr 7·50 Mo 0·50	1,050 in oil	850 in air	13·3
Jessop H48 XCR type	Inlet and exhaust	Good hot strength and resistance to lead attack. Hardenable	Narrow forging range	C 0·45 Mn 0·70 Cr 24·0 Si 0·60 Ni 4·70 Mo 2·9	780 for 14-16 hr air quench		15·75
Jessop R18 D.T.D. 282 En 55	Exhaust, for petrol and diesel engines	Better lead attack and scaling resistance than En 54 at about 900 deg C		C 0·35 Ni 8·0 Si 1·80 Cr 18·0 W 3·50	1,050 in air		17·5
Fox Silcrome S.T.A.5 V24, D.T.D. 13B En 52	Petrol and heavy diesel exhaust	Inexpensive material, production easy		C 0·40–0·50 Mn 0·30–0·60 S and P 0·04 max Si 3·0–3·75 Ni 0·50 max Cr 7·5–9·5	1,050 in air or oil according to mass	850–880 in air or oil	13·6
Nimonic 80 D.T.D. 725	Very high performance engines, where reliability is of prime importance	Exceptionally good resistance to lead attack and corrosion and very good mechanical properties at high temperatures	Expensive	C 0–0·1 Cr 18–21 Fe 0–5·0 Si 1·0 max Ti 1·8–2·7 Co 0–2·0 Mn 1·0 max Al 0·5–1·8 Ni remainder	Solution treatment 8 hr at 1,080	Ageing treatment 16 hr at 700 air quench	14·0

noticed, the valve soon fails to seat properly, and blow-by and burning occur.

The corrosive conditions under which valves have to operate appreciably reduce the fatigue strength of the materials from which they are made. Moreover, in some instances, corrosion alone around the hottest part of the neck causes serious reduction of the cross sectional area. Although most of the impurities in the proportions experienced in commercial grade diesel and petrol engine fuels have little effect on valve life, except possibly under cold-running conditions, tetra-ethyl-lead additive may have a seriously detrimental effect on certain materials.

The type of lubricating oil, apart from affecting the tendency of the valve to stick in its guide, has a marked effect on corrosion. The reasons for this are not fully understood but it is possible that certain additives may have a catalytic effect and accelerate deterioration. Alternatively, some types of oil may chemically change the nature of the deposits on the valve, causing them to break off more readily. The ability to develop on the valve surface a continuous, stable and adherent protective oxide layer at operating temperatures is probably a most significant factor from the point of view of length of life. Unfortunately, this protective film does not have the same thermal expansion characteristics as the metal underneath it. It may, therefore, be broken loose by wide variations in surface temperature.

If an engine is run for long periods at relatively light load, exhaust gas contaminants of low melting point may be deposited on the valves. Then, when the temperature is raised to a higher level under different operating conditions, these deposits may become very active and, until they are dissipated by the heat and gas flow, cause serious damage to the valve.

Cold corrosion also tends to take place. When low grade diesel oils are employed, sulphur dioxide, sulphur trioxide and other gases are developed from impurities during the combustion process. These combine with the water formed by the burning of the hydrogen content of the fuels to form acids which, at low temperatures, are deposited as dew on the valves and other components that they contact. Even higher grade oils and petrols are not entirely free from corrosive contaminants. Cold corrosion is most likely to occur in vehicles used for short door-to-door delivery work and when low grade diesel oil fuels are employed.

Materials

From the foregoing, it can be seen that the desirable properties for valve steels are:—

(1) Resistance to scaling at temperatures up to those at which the valve operates. Alternatively, if scale does form, it must not readily break away from the metal.
(2) Resistance to both hot and cold corrosion.
(3) Good strength and hardness at operating temperatures.
(4) High impact strength under both hot and cold conditions.
(5) Good wearing characteristics are necessary for valve stems and seating faces.
(6) High thermal conductivity at working temperatures.
(7) Low coefficient of expansion.
(8) Resistance to thermal and mechanical fatigue as well as to creep.
(9) The material must be readily forged and machined.
(10) It should be easily heat treated and capable of being hardened at the stem end.
(11) Low cost is also an important feature.

The alloy steels actually used fall roughly into three groups. First is the ferritic group, of which Silcrome 1, Silcrome XB, En 52 and En 59 are examples. In general, the ferritic materials can be hardened by heat treatment and are relatively easy to work in the steel mill and in subsequent manufacture. These materials have quite good thermal conductivity and a low coefficient of expansion. Their hot hardness is relatively low, and their resistance to fatigue, corrosion and creep is in most instances lower than that of the other groups. Because of its high chromium content, XB steel is much superior to Silcrome 1 for exhaust valves for petrol engines. It has good hot and excellent cold corrosion resistance.

In the second classification are the austenitic steels, of which En 54, D.T.D.49B, K.E.965 and Jessop G.2A are examples. Steels in this group have excellent hot strength and good corrosion and oxidation resistance. Moreover, their creep resistance properties are good, and their hot hardness is higher than that of the ferritics. However, they are difficult to forge and machine and can only be work hardened. Some materials in this class are subject to carbide precipitation and the seating faces of valves made from them may tend to pit. These steels also have a high coefficient of expansion, which involves the incorporation of large clearances between valves and guides and introduces problems in connection with the maintenance of tappet clearances. The thermal conductivity of the austenitic steels is lower than that of most of the others.

Finally, there is a sigma precipitate group. This includes the XCR and XCT materials. Steels in this group have exceptionally high hot-hardness. So far as thermal expansion and conductivity are concerned, the values obtained for the sigma precipitate materials are between those for the steels in the other two groups. These steels can be hardened by a long heat cycle, but during this process they contract. Both in the steel mill and in subsequent manufacturing stages, they are difficult to process.

Composite valves have also been made, but are more widely used in America than in this country. For example, stems of materials that have good bearing properties in cast iron guides and which may be hardened, are sometimes welded to heads of austenitic steel. The austenitic steels are very resistant to the corrosive action to which valve heads are subjected, although they do not resist very well the hammering action on stem tips and generally tend to wear in guides more readily than other materials. They also have other properties which recommend them for use under high temperature conditions.

Valves of this type are generally expensive to produce and therefore are not widely used in Europe. In America, however, where a large proportion of the commercial vehicles are powered by petrol engines, apparently 25-30 per cent of the exhaust valves produced for engines of this type are of composite construction. They generally have heads of XCR or variations of 2112 material welded on to S.A.E.3140 stems. Even hard facing, because of the extra cost involved, is only adopted in Europe for heavy duty engines, although there is a strong case for the wider employment of faced valves for engines that are run for long periods continuously at high temperatures. The best insurance against valve failures is the employment of the best materials.

Stellite or other alloys may be used to face the valves in the seating areas to make them hard enough to prevent their being indented by particles of deposits dislodged from the combustion chamber and trapped between them as the valve closes. Surface treatments are sometimes applied to valve stems to improve their wearing properties. For example, austenitic steels may be nitrided, but the injurious effects of tetra-ethyl-lead on nitrided surfaces tends to discourage this practice. Recently, experiments have been in progress on the use of dry lubricants, such as molybdenum disulphide, on valve stems. There may well be a future for the use of these lubricants. Chromium plated stems have also been employed.

One of the most recent developments is the Tranco S.A.S. valve, produced by the Farnborough Engineering Co. Ltd. This valve incorporates an armoured seat of a special alloy, which has been developed to increase the service life of the valve. It is offered to replace valves where premature burning has been experienced. An advantage of facing with an alloy of this type is that if blow-by, due for example to cylinder head distortion, takes place, the seat resists for some time the effect of the high temperatures developed. During this time, loss of power is experienced and gives warning of impending failure. When poorer quality materials are used, the deterioration is generally rapid and, because failure ensues so quickly, break-down may occur on the road.

Nimonic 75, 80 and 90 are examples of high quality materials sometimes used for valves. The equivalent standard specifications of Nimonic 75 and

TABLE II. MECHANICAL PROPERTIES OF A SELECTION OF BRITISH STANDARD AND PROPRIETARY MATERIALS SUITABLE FOR VALVES

	Properties at Room Temperature						Properties Hot			Creep	
Make and Equivalent B.S. Spec.	Ultimate Tensile Strength ton/in²	Yield Point ton/in²	Elongation per cent, on 2 in	Reduction of Area per cent	Izod Impact ft-lb	B.H.N.	Temperature deg C	Ultimate Tensile Strength ton/in²	B.H.N.	Temperature deg C	Stress for creep rate of 0·1 per cent in 1,000 hr, ton/in² (10^{-6}/hr)
En 51	52	38	22	65	40 min	229 max				427	5·5
En 52 Silcrome type	57		24		9 approx	255–293					
En 53	60		20	40	12 min	235–285				450 650	8·0 1·5
En 54 Austenitic	53		31		15 min	302 max				650 750	8·0 3·0
En 59 XB type	60		15		Not less than 47 Rockwell C						
Jessop E1A En 51	51		25		60	235 Annealed, 228	600 700	15 6			
Jessop G2A S.T.A.5 V26, D.T.D. 49B En 54	53		31		35		600 700 800	33 24 16	194 176	650 750	8·0 3·0
Jessop G32	66	53	8	5	8	302	600 700 800	48·5 45 38·5		650 750 800 900	19·0 11·5 8·5 (3)
Jessop H3 D.T.D. 311 En 53	65		24		15	293 Annealed, 269	600 700 800	20 8 4		450 550 650	8·0 3·1 1·5
Jessop H18 S.T.A.5 V24, D.T.D. 13B En 52	57		24		9	269	600 700		169 87		
Jessop H29 En 59 XB type	60		15		15	277	600 700 800	20 9·5 5			
Jessop H38	67		25		11	302 Annealed, 269	600 700 800	22 10 3·5			
Jessop H48 XCR type	67		11		8	302	600 700 800	37 27 15			
Jessop R18 D.T.D. 282 En 55	54·4		31	40 at 600 deg C	46		600 800	33 16			
Fox Silcrome S.T.A.5 V24, D.T.D. 13B En 52	59·2	48	26·5	50	6	255–293				650	Only figures available are: At 1 ton/in² stress, creep at 500 hr is $6{\cdot}7 \times 10^{-6}$ in/in/hr
Nimonic 80 D.T.D. 725	71* 77†	35* 46·5†	30* 28†	36* 30†	37* 34†	245 min, heat treated				600 650 700 750	21·5 16·5 11·0 6·0

*After creep test at 700 deg C and 7 ton/in² for 4,160 hr, and subsequently cooling to room temperature.

†After creep test at 750 deg C and 4 ton/in² for 2,660 hr, and subsequently cooling to room temperature.

80 are D.T.D.703 and D.T.D.725. They are both 80 per cent nickel, 20 per cent chromium alloys, but Nimonic 80 has small additions of titanium and aluminium. Nimonic 90 is the equivalent of D.T.D.747 and contains 62 per cent nickel, 20 per cent chromium, 18 per cent cobalt and small percentages of titanium and aluminium.

These materials are all very resistant to lead attack and to corrosion at high temperatures and their creep resistance is exceptionally good. For these reasons, they are also employed for the blades in gas turbine rotors. However, the alloys are not wear resistant unless work hardened. Therefore, the stems of valves made from Nimonic alloys are work hardened, and in this state give good service. A Brinell hardness figure of 500-600 can be obtained by cold drawing. Valves made from these alloys can be extruded or upset forged with equal facility. A satisfactory method of manufacture is to electrically upset and forge cold drawn bar of 350-450 B.H.N. Subsequent ageing increases the hardness by 50-75 B.H.N.

Nimonic valves are particularly suitable for marine applications, where corrosion is a serious problem particularly when inferior grade fuels are used. They have also been used in aircraft, motor vehicle and motor cycle engines. In one motor cycle application, Nimonic 80 valves are used in conjunction with aluminium bronze guides with 0·001 in clearance between them. Nimonic 75 can readily be flash butt welded and has been used for heads of welded two-piece valves.

The seating faces, and in some instances the whole heads, of valves are sometimes coated with B.A.C. Brightray. The initials B.A.C. stand for the Bristol Aeroplane Company, who were the first to use this material for coating valves. The alloy is made by Henry Wiggin and Co. Ltd., who also manufacture the Nimonic materials. It is an 80 per cent nickel, 20 per cent chromium alloy and, like the other alloys of this type, has exceptionally good resistance to attack by lead and vanadium pentoxide, as well as to general corrosive conditions. These properties make it particularly suitable for valves of engines that operate on low grade diesel fuels. The material is soft enough to seat well, and it work hardens so that after it has bedded down to the seat, further sinkage does not take place. The hot hardness of Brightray is appreciably greater than that of alloy steels, but because of its ductility it does not tend to crack.

Practical applications

The properties of some valve steels and other alloys are given in Tables I and II. Materials used for exhaust valves include British Standard steels as well as proprietary brands. Of the British Standard materials, En 52 is generally employed in diesel and low-powered petrol engines. Valves of En 59 are fitted on modern petrol engines to resist attack by leaded fuels. In highly rated petrol engines, and also in some diesel units, En 54 valves and sometimes bi-metal valves with En 54 heads and En 18B or En 24 stems, are employed. Heavy duty petrol and diesel engines for commercial vehicles are sometimes fitted with En 52 exhaust and inlet valves faced with Stellite or other hard alloy material. In some diesel engines, En 54 is used as the basic material and is faced in a similar manner.

The choice of steels for inlet valves presents few difficulties. In certain circumstances, cold corrosion resistance may be more important in these valves than for those used in the exhaust system. This is probably because the hard oxide films formed on exhaust valves tend to protect them to a greater extent against cold corrosion, and also because exhaust valves warm up quicker than inlet valves. In general, En 21 and En 22 materials are used in large diesel engines running at low speeds and under cool conditions. The En 24S and En 51 steels are employed mainly for medium and light diesel engines with either shrouded or plain valves. Some of the cooler running petrol engines have En 18B and En 51 valves, but for most modern petrol units, En 52 is specified.

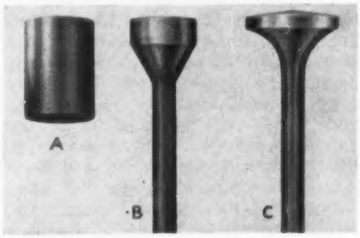


Fig. 2. Three stages in the extrusion process. A, the slug. B, the stem extruded. C, the head forged

Production

A number of different processes are used in the production of valves. Each has its advantages and disadvantages. Some valves, produced in small quantities, mainly for use under severe operating conditions, are hand forged. An extremely high standard of skill is required for this process, but the valves made in this way are generally of the best quality. During the hand forging operation, the stock is worked sufficiently to reduce the grain size and a good grain flow can be obtained. The slowness of the operation, and the fact that fairly generous machining allowances are necessary, combine to make the process expensive.

Large valves made in relatively small quantities are usually manufactured by the hammer or Goff process because the tooling costs are relatively low. Small and medium sized valves in large scale production are generally made by electrically upset forging or by extrusion. Although when electrically upset forging was first introduced it was widely regarded with suspicion, the failures of valves made by this process were probably to a large extent due to inadequate control of the manufacturing process. However, subsequent development has led to the consistent production of flawless valves by this method.

The sequence of operations in the electrically upset forging process is as follows. First, the bar is cut off accurately to length and then, to ensure close control of its electrical resistance, it is ground accurately to a diameter about 0·015 in larger than the finished size. The lengths are next fed to the upsetting machine, which consists essentially of two main components. One is a hydraulic ram, fitted with a split grip which holds the pin in position and also acts as the positive pole of the electric circuit; the other is a retractable anvil which acts as the negative pole. During operation, the pin is held by the split grip and moved forwards by the ram until contact is made with the anvil. This completes the electric circuit, and current flows through the pin to generate the heat necessary to make the metal soft enough for upsetting. Further forward motion of the ram completes the upsetting operation. During the last part of this process the anvil is usually retracted at a slower speed than the rate of advance of the ram.

It is important that there should be no arcing between the upset end and the grip. If it does occur, the metal is burned and the structure cannot be restored by heat-treatment. Probably much of the early prejudice against electrical upsetting valves arose from defects experienced as a result of arcing. The operations subsequent to upsetting are: Hot forging, followed by stripping the flash. Then the components are heat-treated and the stems are straightened where necessary and the heads trued.

The extrusion process can also be used for rapid production of automobile engine valves by semi-skilled labour. In this process the valve begins as a slug, shown at A in Fig. 2. This may be sheared or, for high grade valves, sawn from the bar stock. The length: diameter ratio of the slug has a considerable influence on the amount of work put into the material during the process, and therefore on the grain size and flow.

After being heated to the correct temperature, the slug is fed into the die and the plunger forces most of it through a tapered hole to form the stem and neck of the valve. The resultant shape of the metal is shown at B, Fig. 2. Next, the valve is removed from the die by an ejector pin and is transferred to the finishing die, in which the head is pressed approximately to the finished form, as in C, Fig. 2.

In the extrusion process, the grain tends to be pressed closely together. On the other hand, an opening out or bursting effect is obtained by the electrical upsetting process, in which the upset end is formed into a more or less spherical shape before it is forged to the finished shape. Some authorities,

Fig. 3. Four types of valve head. From left to right: flat, tulip, modified tulip, and mushroom

therefore, maintain that extruded valves are slightly superior to electrically upset ones. However, the final forging operation doubtless does much towards closing and refining the grain.

The essential feature to be aimed at is the avoidance of end grain on the valve seating face since, under certain conditions, this may lead to severe pitting. Grain flow parallel to the seating face can be obtained both by the extrusion and electrical upsetting processes. With both methods valves can be produced to very close limits, so that only a small amount of metal has to be removed during the machining operations. This is important, both from the economic point of view and because it helps in the avoidance of end grain conditions.

Valve forms

In determining the best shape for engine valves, the following general requirements must be met. The head section should be rigid enough to support the loads without undue deflection. On the other hand, it must not be too heavy, otherwise inertia loading will be too high, not only on the valve but also on its actuating mechanism.

It is necessary to provide an adequate thickness of metal adjacent to the rim to conduct heat from the centre of the head away through the seat, but the rim must not be too stiff, otherwise it will not readily accommodate itself to seat distortion, and blow-by might occur at the seat face. A slight degree of distortion either of the cylinder head and seat or of the valve is almost inevitable. Since a large proportion of the heat flow from the valve takes place through the seat, it is desirable to have a wide face; but this is a matter for compromise, for it is more difficult to obtain a perfect gas seal with a wide seat. Moreover, solid particles of the products of combustion are more readily trapped between wide seat faces than between narrow ones.

A generous radius between the head and the stem tends to facilitate gas flow, but at the same time it adds to the weight of the valve. Large radii also reduce stress concentration. The stem diameter should be of sufficient magnitude to allow heat to flow easily along its length and away through the guide to the water jacket. In one design, it was found that by increasing the valve stem diameter by 0·060 in from 11/32 in, the temperature of the valve throughout the speed range was reduced by about 23 deg C. Again a compromise is called for since a large diameter stem increases the weight of the valve and also obstructs the gas flow.

Four types of head are shown in Fig. 3. The tulip type has been widely used in aircraft and racing engines because it is strong, light and is thought to facilitate gas flow through the port. It is most suitable for inlet valves and is rarely, if ever, used for exhausts because the surface area exposed to the hot gas both under the head and at the neck is larger than that of other types of valves. The modified tulip form is probably more satisfactory. With this type of valve head there is a relatively large amount of material backing the seat, so that in the event of localized gas blow-by, the heat transferred to the valve is readily conducted round the rim. Furthermore, the shape is such that expansion due to local overheating tends to close the gap between the valve and its seat.

The mushroom type head is used in some heavy petrol engines, mainly for commercial vehicles. It is stiffer mechanically than any of the other designs, but this is not necessarily an advantage. Moreover, the shape of the head is such that it offers a relatively large surface area to conduct heat from the combustion chamber.

Flat heads are most widely used. This form has many advantages, among which are ease of production and therefore low cost. The head section should not be too thin but, on the other hand, the projection of the head into the combustion chamber should be as small as possible. Screwdriver slots and other indentations in the undersurface of the valve heads should be avoided, since they tend to lead to stress concentrations, local overheating and distortion.

Detail design

From Table III it can be seen that, on the subject of seat angles, there are differences of opinion as between one manufacturer and another. An argument often put forward is that the 45 deg angle is best for exhaust valve seats, because it is more conducive to the maintenance of a satisfactory seal than is a 30 deg angle. However, the validity of this argument is in doubt when very narrow seats are employed. The 30 deg seat is said to give a better discharge coefficient and so some authorities claim that it is more suitable for inlet valves. This is probably too sweeping a generalization.

Some manufacturers specify a ½-1 deg differential between included angles of the valve face and seating in the cylinder head, Fig. 4. This is because, under running conditions, the hotter areas of the valve face, that is, the parts nearest to the throat, expand more than those nearest the head and the two faces tend to run parallel. Without the interference fit the tendency is for the seating faces to open slightly towards the combustion chamber and thus to allow solid products of combustion to be forced between them. This effect

TABLE III

Engine	Material		Head diameter		Stem diameter		Seat Included Angle
	Inlet	Exhaust	Inlet	Exhaust	Inlet	Exhaust	
Daimler Regency	Jessop H3	Jessop H29, or XB	1 9/16 in	1 3/8 in	3/8 in	3/8 in	
Fordson Major	En 18B	XB	1·730-1·720 in	1·543-1·533 in	0·3734-0·3730 in	0·3733-0·3723 in	Valve 59 deg Seat 60 deg
Commer 4·1 litre	En 52	XB	1·745-1·741 in	1·515-1·511 in	0·3735-0·3728 in	0·3735-0·3728 in	
Lea Francis 2½ litre	En 53	En 54	1·75 in	1·59 in	0·312 in	0·312 in	
Vauxhall EIP and EIX			1·375 in	1·25 in	0·311 in	0·310 in	Inlet 58 deg Exhaust 88 deg
Austin A30	Silcrome No. 1	XB	1 3/32 in	1 in	0·2812 in	0·2795 in	
Perkins R6	En 18S	En 52	1·848-1·8444 in	1·598-1·594 in	0·3745-0·3735 in	0·3745-0·3735 in	Valve 90 deg Seat 89 deg
Perkins P3	D.T.D. 13B		1 9/16 in	1 5/16 in	5/16 in	5/16 in	90 deg
Ford Cost Cutter	S.A.E. 8645	XB	1·730-1·720 in	1·543-1·533 in	0·3742-0·3731 in	0·3733-0·3723 in	60 deg
Armstrong Siddeley Sapphire	Silcrome No. 1	XB	1·700-1·695 in	1·490-1·485 in	0·341-0·340 in	0·341-0·340 in	90 deg
Standard Eight	Silcrome No. 1	XB	1·121-1·117 in	0·996-0·992 in	0·3110-0·3100 in	0·3090-0·3080 in	90 deg

is probably negligible with small valves, but it is an important consideration with the larger ones.

Practices regarding seat widths show even more variation than do seat angles. This is not surprising, for a large number of factors have to be considered. As has already been stated, a wide face tends to improve the dissipation of heat from the valve, but this tendency is offset to some extent by the fact that the contact pressure, in lb/in^2 of seating contact, is lower, and also there is more chance for particles of solid products of combustion to be trapped between the faces.

The hardness of the material used for the valve and the seat, as well as the closing velocity of the valve, must be taken into account when the face width is specified. Another factor that has to be considered is the probable life between overhauls. On well maintained commercial vehicle engines, in which valves and seats are re-ground at regular intervals, seat deterioration is not such a serious problem as in private car engines. In small valves of $1\frac{1}{4}$-$1\frac{3}{8}$ in head diameter, seat widths of $\frac{1}{16}$-$\frac{3}{32}$ in are generally regarded as satisfactory, while in larger valves widths of $\frac{3}{32}$ in-$\frac{7}{64}$ in are common. The face on the valve is always wider than that on the seat in the port. This is because valves are usually harder than the seats, and in any case valves may be re-ground readily if the faces become shouldered, whereas repeated re-grinding of the seat might lead to the cylinder head having to be scrapped.

It is important that the concentricity of the valve seat and the guide bore axis should be maintained within close limits. With valves of 1-$1\frac{1}{2}$ in head diameter, the greatest eccentricity that can be allowed is 0·002 in, and with larger valves, 0·0025 in. Smaller tolerances than this are preferable.

There are three main essentials so far as stem design is concerned. The first is that the diameter should be large enough to allow heat to be conducted readily up to the guide. Secondly, it should be hard enough to prevent wear or scuffing in the guide. Thirdly, the fillet radius between it and the head must be as large as is necessary to prevent undue stress concentrations and to give good gas flow characteristics.

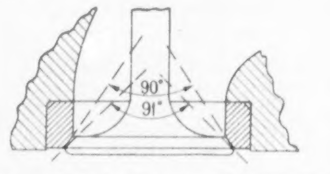


Fig. 4. In some designs an interference angle of about 1 deg between the valve face and seat is specified

Stem diameters cannot be determined by hard and fast rules. This is because in practice they are almost invariably a compromise between what is most desirable to give maximum engine efficiency and what is economically best from the point of view of rationalization. The problem is further complicated by differences in cooling arrangements as between one design and another.

So far as rationalization is concerned, a practice frequently adopted is to make one size of valve common to a range of engines, usually with different numbers of cylinders, but all of the same bore. In addition, some manufacturers specify common inlet and exhaust valve guides. In these cases, their exhaust valve stem diameters are slightly different from those of the inlet valves to give the appropriate clearances.

Exhaust valve stems, because of the large amount of heat they have to conduct away, should theoretically be of larger diameter than inlet valves. So far as gas flow is concerned, this condition is acceptable because the exhaust gases are forced out by relatively large pressures. On the other hand, inlet stems should be as thin as possible so as not to obstruct gas flow. Since they run at lower temperatures, because of the cooling effect of the incoming gases, heat dissipation is not a serious problem. However, over 90 per cent of engines currently in production have inlet and exhaust valves with virtually a common stem diameter so as to help to balance the reciprocating weights.

In general, the ratio of inlet valve head area to stem cross sectional area is usually between about 19:1 and 25:1. The ratio for exhaust valves varies more widely. On recently designed small engines, developing 25-30 b.h.p., a ratio of about 12:1 has been adopted. A fairly large manufacturer whose products are well known for their reliability appears to favour a ratio of about 13:1 to 14:1 for engines of 3-$3\frac{1}{2}$ litres capacity. Many quantity produced diesel and petrol engines of 1-4 litres swept volume have ratios between 16:1 to 19:1. In some higher performance engines, with hemispherical combustion chambers, ratios of between 20:1 to 26:1 have been adopted, but good quality materials are specified for the valves.

Most manufacturers adopt parallel stems, but a few taper their exhaust valve stems to reduce the diameter towards the head, Fig. 5. This measure is adopted to take into account the effect of the temperature gradient on the amount of expansion. In other words, the aim is at having a parallel stem under normal hot running conditions.

A number of designers favour a slight undercut round the valve stem at a point about $\frac{1}{4}$ in inside the end of the guide when the valve is closed. This is said to prevent damage due to carbon build-up on the stem adjacent to the base of the guide. Probably this effect is obtained because the increased clearance between the stem and the lower end of the bore of the guide allows the carbon to build up to a greater thickness and the thick coating flakes off more readily than a thin film. In most instances, the undercut is about 0·02 in on the diameter, but much larger ones have been used. An objection to this measure is that it tends to introduce a stress concentration in the area where the valve operating temperature is highest. However, it appears to give satisfactory results providing the valve loading is not unduly heavy.

A surface finish of 10-20 micro-in is usually specified. This is smooth enough to discourage adhesion of

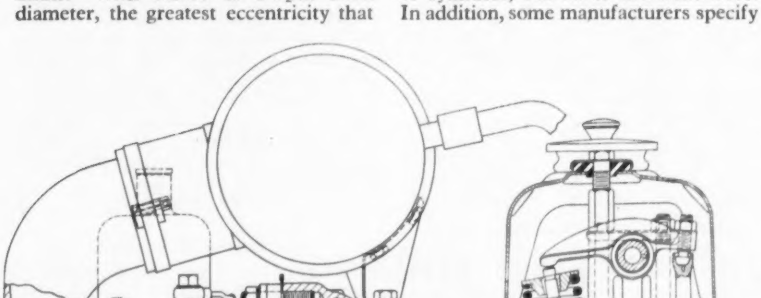


Fig. 5. The stems of the exhaust valves in the Daimler Regency are tapered towards their lower ends to allow for variation of radial expansion along their length, due to the temperature gradient

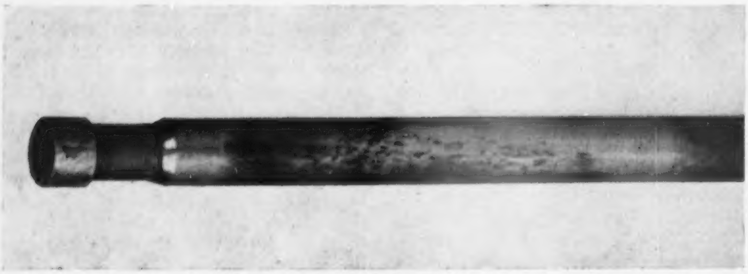


Fig. 6. Severe scuffing has taken place between this valve stem and the guide because of dry operating conditions and carbon build-up in the clearance

deposits on the stem. At the same time, it is not so smooth as to prevent the oil film from wetting the surface. This finish has been found to give good wear resistance provided the stem and guide materials are suitable.

Many different spring retaining devices are currently in use and it is not practicable to give details of all, but the general principles to be followed can be stated. It is of fundamental importance that undue stress concentrations are not introduced and that bending loads are not imposed on the stem. Good results have been obtained with split collets that are relatively thin and therefore tend to wrap round the valve stem and contact a large area. Thick collets often cause galling locally where they contact the stems. If tapered collets are used, a taper angle of about 15 deg gives good results. To reduce the tendency towards stress concentrations, a fairly wide groove round the end of the stem is recommended.

A feature that is often overlooked is that valve springs, the ends of which, in the free state, are square with the axis, tend, if compressed between ball-and-socket end fittings, to go out of square. As a result, in the assembled state they constantly impose a bending moment on the stem and cause wear in the guide. This can be remedied by suitable spring design.

Circlips are in some instances fitted in grooves round the ends of the stems so that in the event of a spring breakage it is impossible for the valve to fall down into the cylinder and cause damage to the engine. Objections are sometimes raised to the use of circlips in this way on the grounds that the grooves give rise to stress concentrations. However, it is doubtful whether this effect is serious except, perhaps, in small valves, where the ratio of groove depth to stem diameter is particularly unfavourable.

The clearance between the valve and the guide should be arranged so that at maximum working temperature it is only just large enough to contain an adequate lubricating oil film. This is important for a number of reasons. Firstly, a large clearance between inlet valves and their guides may lead to a weakening of the air-fuel mixture at small throttle openings, and adjustment to the carburettor to remedy this may give rise to excessive fuel consumption because of an over-rich mixture at large throttle openings. In supercharged engines, the maintenance of the correct clearances is not so critical from this point of view. In unsupercharged engines with large clearances in inlet valve guides, oil consumption may be excessive because of the tendency for oil splash and mist to be drawn down the guides into the induction system. This may lead to other troubles, such as plug and exhaust valve fouling. A number of manufacturers fit felt or rubber rings round the stem in the base of the collets to restrict the amount of oil that can flow down into the guide.

If the clearances between both the inlet and exhaust valve stems and their guides are too large, fatigue failures may occur at the junction between their heads and their stems. These failures occur as a result of the valve alternately making contact first on one side of its seat and then on the other, and thus imposing alternating bending stresses on the valve. In addition, excessive clearances encourage the build-up of deposits, which reduce the effectiveness of lubrication and lead to scuffing, Fig. 6. In passenger car engines with stem diameters up to ⅜ in, the clearances generally adopted range from 0·001-0·003 in inlet, and 0·002-0·004 in exhaust. For stem diameters greater than ⅜ in, the clearances are usually between 0·002-0·004 in inlet, and 0·003-0·005 in exhaust. If the valves operate under conditions of extreme temperature or if the materials from which they are made have a large coefficient of expansion, greater clearances may be adopted.

The rates of wear experienced vary between 0·002 in in 100,000 miles and 0·002 in in 5,000 miles. An acceptable figure is the mean of these two rates. As the clearance becomes larger, so does the rate of wear increase. This is probably because, as the clearance increases, contact tends to take place in local areas instead of over the whole length of the stem. Moreover, operating temperatures become higher because of the poor contact between the stem and guide, and lubrication deteriorates as a result of the build-up of gum and other deposits in the clearance. Therefore, guides should be replaced in service when the clearance becomes 2½ to 3½ times that initially specified. They should also be replaced if they become bell-mouthed at either end.

(To be continued)

REDUX IN FILM FORM

REDUX bonding adhesive, developed by Aero Research Ltd., Duxford, is now available in a new form that should contribute towards greater ease and economy in use. It consists of the identical Redux liquid and powder supplied as a film, expressly, but not exclusively, for bonding metal skins to metal honeycombs to make sandwich structures.

The film is supplied in rolls with protective covering and has a storage life of at least six months. For bonding panels to honeycombs, it is first consolidated on to the metal skin under heat and vacuum pressure, with a sheet of aluminium foil placed between the film and the rubber blanket to prevent sticking to the rubber. The heating cycle for this operation is 10 minutes at 145 deg C.

After cooling, the aluminium foil is stripped off and a coating of Redux 120 applied by brush over the partially cured film. Redux 120 should also be applied to the edge of the honeycomb. The Redux 120 is dried at 80 deg C for 30-60 minutes before the skins and honeycombs are assembled and the adhesive is cured at 145 deg C under vacuum pressure. The curing time will depend upon such factors as the thickness of the honeycomb. It may be assumed to be about one hour for a ½ in thick honeycomb core sandwich heated one side only.

Tests to destruction at room temperature have shown the failing load on lap joint specimens, cured under vacuum at 12 lb/in^2 to be in the order of 4,100 lb/in^2. The specimens were 20 s.w.g. DTD.546, 1 in wide and ½ in overlap, pickled to DTD.915 for one hour at 60 deg and cured for 30 minutes at 145 deg C.

An important advantage of Redux film is that it ensures exact control of the proportions of powder and liquid in the bond. This has resulted in improved strength at elevated temperatures.

Redux film can be used for normal metal-to-metal bonding processes, for which the curing cycle is 30 minutes at 145 deg C. It may be expected, however, that the main use of the film will lie in the bonding of skins to honeycomb cores, for which an adhesive is essential. It must be stressed that in neither application is there any necessity for any priming of the metal surfaces before the application of the adhesive.

COLLOIDAL MOLYBDENUM DISULPHIDE

A Lubricant for Many Applications

F. Gordon Kay, A.M.I.Mech.E.

IN metallurgical applications molybdenum has been known for many years as an alloy constituent of special steels, particularly those used in metal cutting operations. The chief source of the metal is the mineral molybdenite, a sulphide of molybdenum found almost exclusively in the United States of America. The structure of the material is of the layer formation, the crystal lattice consisting of a layer of molybdenum atoms with a layer of sulphur atoms on each side. Owing to the weak Van der Waal forces between adjacent layers the shear strength of the substance is low. In this respect the solid resembles graphite.

The molecular structure of molybdenum disulphide accounts for its value as a lubricant. Not only is it in itself a relatively soft slippery substance but it has the property of becoming fixed to the surface with which the particles come into contact. When molybdenum disulphide powder is applied to a surface and the film is rubbed the particles are oriented with their basal planes parallel to the substrate. Adsorption of the particles to the surface results in an extremely thin film being obtained which possesses high lubricity even under relatively high pressures and temperatures. Whilst thermal stability of molybdenum disulphide is less than that of graphite it is stable in air up to 350 deg C. In an inert atmosphere decomposition does not begin to take place until a temperature of between 500 deg C. and 600 deg C. is reached.

Original developments

Originally attempts were made to employ dry powdered molybdenum disulphide as a lubricant but it was found that whilst the frictional characteristics of the film were good it was quickly removed owing to lack of sufficient adhesion of the particles to the surface. In consequence, it did not provide adequate resistance to wear. However, when MoS_2 powder is reduced to colloidal dimensions and stabilized dispersions in volatile carriers are prepared, it is possible to form films that are not robust enough to provide a high degree of wear resistance at relatively high loads and temperature and at the same time are relatively inert and offer a good measure of protection against corrosion.

In practice it is usual to employ a dispersion of MoS_2 in a carrier, which, whilst facilitating application, readily volatilizes under the influence of heat to leave an adherent film of MoS_2 on the bearing surface. This film possesses, in certain cases, a higher heat stability than a film of the dry powder. Therefore, when the appropriate "dag" dispersion of MoS_2 is used, it is possible to utilize the high lubricating properties of the substance at temperatures well above those at which petroleum lubricants are destroyed. Examples of the use of dispersions of MoS_2 for dry lubrication include screw threads, drawing dies, cutting tools and other mechanisms such as typewriters, calculating machines and camera shutters which operate intermittently at normal temperature.

Carrier liquids

The best results are obtained by the use of a colloidal dispersion of MoS_2 in a volatile carrier liquid, which, whilst enabling the dispersion to be applied in a simple manner, evaporates at normal or slightly elevated temperatures, leaving behind a smooth uniform film of MoS_2 firmly attached to the metal surface. The simplest type of coating is obtained by the use of colloidal MoS_2 in alcohol. Harder and more durable films are obtained by the use of dispersions of MoS_2 in white spirit or in toluene to which a resin binder has been added.

Dispersions of the types referred to above are now widely used in industry, not only for the dry lubrication of lightly loaded mechanisms such as those already mentioned but also for the pre-lubrication of dies, moulds, press and cutting tools of various types and as a means of preventing the seizure of screw threads, keys, cotters and other machine components that remain bolted together under pressure for long periods of time before being separated.

According to the manufacturers of "dag" molybdenum disulphide, whose experience of the dispersion and use of colloidal graphite extends over a period of nearly half a century, the correct procedure in forming a dry lubricating film of MoS_2 on dies, moulds, press and cutting tools is as follows:—

The surfaces to be treated must be in the finished machined or polished state and they must be thoroughly cleaned to remove all traces of grease or anti-corrosive compound. Cleaning is best carried out by vapour blasting or vapour degreasing, depending upon the size and nature of the component in question. A dispersion of the correct type, in the required quantity, is then diluted with an additional quantity of the carrier liquid (unless the treatment calls for the use of the undiluted concentrate). This mixture is applied to the surface of the dies or tools by means of a brush or air spray. Generally it is unnecessary to attempt to form a thick film. Colloidal MoS_2 has great covering power and a relatively thin film will consist of a great many minute particles lying one on the other rather like a pack of playing cards.

When the dispersion has been applied, it may be necessary to bake the film in order to obtain the maximum benefits from it. Baking is recommended in such cases as the pre-treatment of cutting tools. These are baked at a temperature of between 200 deg C. and 300 deg C. for half an hour or so according to the composition and tempering requirements of the tool steel and the metal being machined.

In practice it has been found that the pre-treatment of cutting tools with colloidal MoS_2 leads to an appreciable increase in their life between re-grinds. Examples include:—

- Broaches and reamers cutting phosphor bronze . . 50 per cent increase
- Carbide tipped tools working on high tensile steel . . 100 per cent increase
- Saw teeth cutting copper . . 300 to 800 per cent increase

As will be appreciated, the treatment is valuable for a wide variety of tools, particularly those used on the more difficult new metals such as are employed in the aircraft industry.

Treatment of dies

For dies, as in the case of cutting tools, it is the condition of the surface that determines to a very large extent the life of the tools and the quality of the work produced. In the case of press and drawing dies, scuffing due to inadequate lubrication is not only the cause of imperfect articles being produced, it is also the main cause of short die life. Pre-treatment of dies to provide a hard self-lubricating film of MoS_2 is known to reduce considerably the incidence of scuffing during the time that the die is being run in. In a number of cases it has been found possible to produce satisfactory articles immediately from new dies. The treatment of the stock also assists in increasing die life and in enabling a higher rate of production to be achieved.

Bowden, in his investigations on the mechanism of friction, found that under

certain conditions the temperature of a bearing surface may rise to a value equal to the melting point of the metal. When this takes place, high spots on the adjacent surfaces weld together and on breaking away leave a cavity in the surface. The conditions required to give rise to this phenomenon exist in the case of new machinery, the bearing surfaces of which have not been conditioned and impregnated with lubricant. By exercising care during assembly and initial running-in, damage to the bearing surfaces may be avoided; nevertheless, it is frequently the case that scuffing and seizure result from the overheating and welding of high spots on the relatively smooth surfaces. Scuffing is particularly prone to take place on the pistons of internal combustion engines, valve stems and guides, cams, the bearings of crankshafts and on the load face of gear teeth.

For many years it has been the practice to employ a dispersion of colloidal graphite to form an anti-scuffing film on engine pistons and other components, and whilst this treatment continues to be a standard practice of piston and engine makers there is a growing use of MoS_2. This is particularly so in the case of certain very heavily loaded components which it is not possible to run-in under light-load conditions, or where the operating conditions call for the use of lubricants that react chemically with the metal surface to form a high load supporting film.

Dispersions in petroleum lubricants

Whilst there are a great many applications for MoS_2 dispersed in volatile carrier liquids, there is an even greater field for its use in conjunction with conventional petroleum lubricants. It is now some years since the Acheson organization succeeded in preparing, on a commercial scale, a stable dispersion of colloidal MoS_2 in mineral oil. This dispersion now enjoys a wide sale not only in the U.K. and America but also in European Continental and other countries. The dispersion is supplied in the form of a concentrate which is generally diluted before use with a quantity of the oil normally employed for the particular purpose. The extent of dilution is determined by the operating conditions and method of application.

Test data

The load carrying capacity of an oil is increased appreciably by the addition of "dag" colloidal molybdenum disulphide. The data contained in the accompanying table was obtained during tests carried out in a Wieland testing machine in which a steel spindle supported in a steel bearing submerged in a small bath of lubricant is loaded progressively, whilst the machine operates at a constant speed. Load, friction, wear and temperature are measured with each increment of load.

It is significant that as the load increased and the surface of the bearing and journal became impregnated with MoS_2, the co-efficient of friction fell progressively and the temperature reached a constant value as the maximum load was approached. This and similar laboratory test data have been confirmed by the results of practical application of "dag" Product 1124 in connection with many industrial processes and difficult lubrication problems.

Typical applications

Thread rolling is an example of lubricating under extreme load where the presence of a relatively small percentage of a dispersion of MoS_2 has given results only previously obtained by the use of oil containing an extreme pressure additive.

Assembly and running-in: These are operations that must be carried out on all new machinery and engines, and with the anti-scuffing compounds of MoS_2 and colloidal graphite which are available it is possible to obtain properly run-in bearing surfaces more quickly than with plain oils.

Metal Working: The high loads and temperatures met with in such metal working operations as extrusion, deep drawing, forging and pressing call for special lubricants. These may be complex mixtures of soaps, fats and mineral oils, but in many cases improved results are obtained by the addition of colloidal MoS_2.

Cutting oils employed during the machining of tough metals may be improved by the addition of a small percentage of colloidal MoS_2 dispersed either in oil or in water. For straight mineral oils one ounce of the oil dispersed concentrate is sufficient to treat two gallons, whilst in the case of soluble oils one ounce of the water based concentrate should be mixed with five gallons of the soluble oil emulsion. Where such cutting coolants are used with tools that have been pre-treated with the volatile dispersion of MoS_2, an improvement in tool life of upwards of 200 to 300 per cent has been reported when machining high tensile steel.

Data are being accumulated of the value of MoS_2 in connection with many industrial processes where the effective reduction of friction and wear provides a problem for the lubrication engineer and chemist. It is also of interest to record that it is clearly evident that this comparatively newcomer to the list of solid lubricants is filling a gap and establishing itself as a complementary product to graphite, with which it is sometimes used under those conditions where the two different materials in contact with each other give better results than when only one of the substances is employed. Advice on the correct use of "dag" dispersions of MoS_2 for a wide range of industrial uses may be obtained from Acheson Colloids Limited, 18, Pall Mall, London, S.W.1.

LOAD TEST RESULTS

Load No. of plates	Pressure Kg.	Coefficient of friction	Abrasion in plastic remodelling of surface (in microns)	Temperature Degrees Centigrade
1	50	0·240	—	23
5	250	0·270	6	51
10	500	0·220	14	78
15	750	0·189	18	98
20	1000	0·166	24	115
25	1250	0·148	32	130
28	1400	0·130	41	133
29	1450	0·124	46	134
30	1500	0·120	48	134

Wieland Model 1952. Oil, straight mineral, SAE 20, VI 96, Colloidal MoS_2 content 1.0 per cent. Specific pressure of 30 plates equals 6700 Kg/cm^2 (approx. 94,000 lb/in^2). Date of the test 1/9/53.

Magnetic Sorting Bridge

An interesting magnetic sorting bridge is now available from Solus-Schall Ltd., 18-22, New Cavendish Street, London, W.1. It has been specially designed for sorting large quantities of small ferro-magnetic parts. The sorting can be carried out either automatically or by hand. With automatic feeding, the instrument can be left unattended after the acceptance standards have been set. When meter readings are required, they can be taken by unskilled personnel.

The instrument will sort specimens according to heat treatment (structure, hardness, strength) and alloy composition. A standard unit will sort work with a maximum diameter of 1¼ in. and a maximum length of 4 in. Auxiliary equipment can be supplied for larger parts.

There are two fully automatic methods of using the instrument. In one, round or hexagon parts are passed along a vee-shaped channel; in the other, flat parts are carried through the apparatus on a conveyor belt. In each case, electronically controlled sorting gates divide the specimens into three grades, "acceptable," "above tolerance" and "below tolerance," and each specimen is automatically directed to the appropriate bin.

Sorting by hand may be required because it is desired to separate the specimens into more than three categories. By taking meter readings the work can quickly be divided into any number of categories. For hand sorting into three categories, the tolerances can be preset and signal lights will indicate into which category each specimen falls. Testing rates vary from 1,000 to 7,000 pieces per hour according to size. Measurements are not affected by the speed at which the parts pass the magnetization coil.

GAUGING AND TEST EQUIPMENT

Recently Introduced Instruments for Workshop Use

MODERN production is somewhat anomalous in character since it aims at ever higher standards of precision and closer tolerances yet simultaneously requires wider employment of short-trained or semi-skilled operatives. These apparently conflicting tendencies are reconciled, to some extent, by the ingenuity and skill of gauge and tool makers in developing easily handled and easily read instruments for checking work at the machine or on the bench. All the items here reviewed were either specifically designed for use in the workshop, or are of sufficiently robust construction and suitably scaled for that purpose.

Electronic comparator

Despite the utmost care in the design and manufacture of mechanical comparators, some eventual loss of accuracy is probably unavoidable as a result of wear in linkages or gears after prolonged usage. With the aim of virtually eliminating this possibility of wear, the Mollart comparator has an induction-type pick-off head and thermionic valve amplification of the probe movement.

The head was developed by the Electronics Division of Saunders-Roe Ltd. and the circuit includes a constant-voltage control and means to reduce time-lag. Current is taken directly from the ordinary supply mains. Any magnification can be arranged, though if extreme factors are required the mechanical parts of the comparator necessarily must be made more robust and care must be taken to avoid substantial change in ambient temperature. In the current model, the magnification is ×1,000 and the balanced scales are read directly to 0·00005 in. The measuring range is ±0·0025 in and maximum capacity is 7·0 in, with coarse adjustment on the column clamp and fine adjustment by a knurled ring on the pick-off head. Furnished with a tungsten carbide tip, the probe falls only 0·01 in below the end of its tubular shield. Work is inserted directly and no lifter is required.

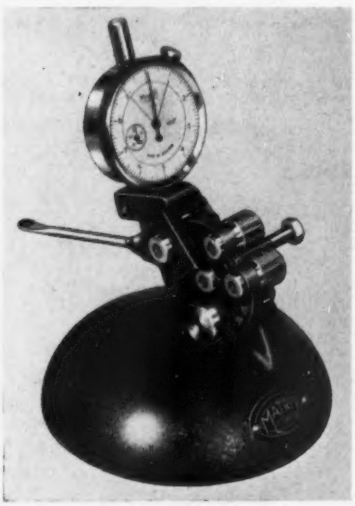
The Mollart electronic comparator is scaled to read directly to 0·00005 in

Construction throughout is sufficiently robust for use alongside the machine in precision production. Housed in a wooden cabinet provided with a carrying handle, it forms a self-contained, portable unit. Another model, to be available shortly, incorporates a variable amplification system and a multi-scaled dial.

Mollart Engineering Co. Ltd., Surbiton.

Thread comparator

Intended for the speedy inspection of mass-produced threaded components, the Matrix Tri-Roll comparator has three full-length rolls to provide a functional check on the work. Errors in pitch, angle, and effective diameter are read cumulatively on a Mercer dial gauge graduated in divisions of 0·0001 in and fitted with adjustable tolerance pointers (not shown in the illustration).



Matrix Tri-roll comparator for mass-produced threaded work

It is first set by means of a master plug corresponding to the size of the work to be checked. Depression of the lever at the rear of the instrument lifts the top roll to allow the plug to be entered and when the lever is released the plug is in pitch with all three rolls. The gauge is then set to zero and the pointers set to the allowed tolerance. Left-handed threads can be checked by reversing the two lower rolls. Where a check is required on effective diameter only, rolls having only two ribs are available. These are truncated on the major diameter and relieved on the minor diameter.

Suitable for use either at the machine or on the inspection bench, the instrument is adjustable on its base to enable it to be set at an angle convenient for operation and reading. It is produced in six sizes accommodating work from 0·10 in to 1·5 in diameter and rolls are available for from 64 t.p.i. to 6 t.p.i. and also for a similar range of metric threads.

Coventry Gauge and Tool Co. Ltd., Fletchamstead, Coventry.

Hardness tester

Weighing only 3 lb, the Burton portable hardness tester gives direct readings in Vickers, Brinell and Rockwell C values on separate, distinctively coloured scales on a large dial. The instrument is merely placed on the work—the ground foot has a vee groove for seating on cylindrical work—and pressure is applied perpendicular to the work surface by both hands on a pivoted grip.

Initial pressure lowers the diamond indentor from its safety position to the work surface and further pressure applies a fixed load. The penetration of the indentor determines the movement of the high-magnification recording mechanism. With a soft metal and a

Direct readings of three hardness values are given by the Burton portable hardness tester

deep depression, the reading is low but the greater resistance of a hard metal reduces the penetration and results in increased travel of the pointer. The work under test should be smooth and clean and it is recommended that the mean should be taken of three readings.

Burton Griffiths & Co. Ltd.,
Montgomery Street, Birmingham 11.

Twist drill comparator

More efficient production and long drill life will result if the drill points are ground symmetrically to the correct angles. The Matrix optical comparator enables a rapid examination to be made for centrality and angle. This instrument comprises a lamp housing, projector, and translucent screen mounted on a substantial cast iron base containing the lighting transformer and fuses. A vee block on the right between the light source and the screen supports the drill which casts a sharply outlined shadow on the screen at a ×5 magnification. The projection lamp is of the 12-volt type.

After insertion, the drill is held to the vee block by a spring-pressed lever and the focus is adjusted by a control knob on the right to give a sharp shadow on the screen. By means of a control on the left, the image is positioned to coincide with the graticule engraved accurately in relation to the locating edge of the screen. Any discrepancy between the angle of the drill and the engraved angle on the screen, or between the drill point and the centre, is immediately apparent. A series of screens is available, each engraved with different angles to suit specific requirements. The capacity of the instrument illustrated is from $\frac{1}{16}$ in to $\frac{1}{4}$ in drills.

Coventry Gauge and Tool Co. Ltd.,
Fletchamstead, Coventry.

Measuring surface finish

To enable the surface roughness of work to be controlled at the machine either by the operator or an inspector, a relatively simple and portable electronic measuring instrument has been developed by Sigma Instrument Co.

Sigma air-operated comparator for selective assembly

Ltd. The C.L.A. value of the surface roughness of the work is indicated directly in micro-inches on the scale of an electric meter. It represents the amplified output from a Piezo-electric crystal activated by a diamond-tipped stylus drawn across the work surface. Hardened and polished skids secured to the underside of the measuring head furnish the reference plane about which the stylus movement is measured.

Overall dimensions of the head are $2\frac{1}{8}$ in long, $\frac{7}{8}$ in high and $\frac{5}{8}$ in wide and normally three skids are fitted. These are arranged one on each side of the stylus at one end of the head and the third at the other end to give a three-point support. They can be reset to other positions if required and specially shaped skids can be substituted for specific applications. Inside the head the crystal unit is free to take up position relative to the skids irrespective of the shape of the work. In its standard form the head will measure the surface of shafts $\frac{3}{8}$ in diameter and over, bores $1\frac{1}{4}$ in diameter and over, and flat faces. The stylus tip is a cone-shaped diamond terminating in a 0·0005 in radius and the loading is approximately 8 gm (0·28 oz).

In use the head is placed on the work surface and drawn along by hand at about one inch per second, but the velocity is not critical. It should be used in an approximately horizontal position to ensure correct loading. An automatically tracking head is also available. The head is held stationary on the work and the measuring unit is drawn along inside the casing for a distance of half an inch at a constant speed by a spring-driven clockwork mechanism.

The amplifier unit is mounted on a chassis that can be readily detached from the carrying case. It is accessible by way of a hinged lid at the back of the case, which also incorporates a compartment in which to store the measuring head and its connecting cable. Internal controls are provided for the individual adjustment of each of the four amplification ranges, which are selected by means of a knob on the front of the instrument and read on one of two scales on the meter dial. The scale ranges are from 0-5, 0-10, 0-50 and 0-100 micro-inches respectively and are suitable for all classes of work from fine lapped surfaces to medium or rough machining.

As supplied, the instrument is calibrated against accepted standards in all ranges. For the routine inspection of quantity-produced work, it is recommended that an approved component be examined on a laboratory instrument and then reserved as a setting master. The calibration can then be adjusted to this master and the instrument used as a comparator against surfaces of similar texture and geometric shape.

Sigma Instrument Co. Ltd.,
Letchworth.

Gauging for selective assembly

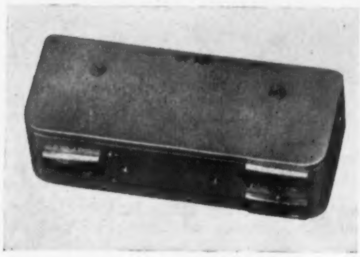
A Sigma three-tube Liquicolumn pneumatic comparator is adapted for gauging parts for accurate selective

Twist drill points can be checked for grinding errors on the Matrix optical comparator

Sigma electronic surface finish tester gives a direct reading in micro-inches

assembly. In the case of pistons and gudgeon pins, as illustrated, the measuring fixture has a twin-jet plug gauge for the piston and a twin-jet ring gauge for the pins. Magnification is adjustable between wide limits: between $\times 5{,}000$ and $\times 10{,}000$ with direct air jets. At $\times 10{,}000$ magnification the scale range is 0·001 in with divisions to 0·00002 in. Lettered or coloured scales can be fitted to make the instrument suitable for unskilled operation.

Sigma Instrument Co. Ltd., Letchworth.



Sigma measuring head for surface finsih tester

Solex air-operated gauges

Workshop comparator

The understandable reluctance to install sensitive measuring instruments in the workshop for use by semi-skilled machine operators should be overcome by the new Solex comparator. Designed specifically for such duties it is simple and robust in construction and the pneumatic measuring head can withstand mishandling and even dropping from a considerable height without its accuracy being affected. This component has a tungsten carbide tipped probe, movement of which varies the amount of air passing through metering jets and a poppet-type valve. The comparator is used in conjunction with a standard Solex air controller fitted with a scale giving a $\times 4{,}000$ magnification and spacing increments of 0·0001 in at about ½ in. Maximum capacity is 6·0 in with a measuring range of 0·004 in.

Solex air-operated workshop comparator

A tenon slot across the heavy base allows tungsten-faced vee blocks, lapped circular tables, lapped square blocks or, for heavy use, tungsten carbide blocks to be fitted as required. An adjustable back stop is also available. Vee blocks can be used to obtain a check for lobing condition on cylindrical work. If a rapid change from a flat table to vee blocks is necessitated, a compensated scale substituted for, or mounted alongside, the standard scale obviates the need for resetting.

Should the instrument be required for inspection, a $\times 12{,}000$ magnification can be obtained merely by changing the control jet and the scale. Increments of 0·0001 in are then spaced at about 1⅛ in and subdivided to 0·00002 in but the range of measurement is reduced to 0·0015 in.

Plug gauges

Jet type plug gauges are now produced in wide ranges of sizes which permit interchangeability, with a single control jet and scale on the controller. Comparator type plug gauges with tungsten carbide tipped probes, for use on work directly from the machine and prior to cleaning, are available for bores of from 1·125 in to 6·0 in diameter.

The duplex plug gauge illustrated is a standard model intended for a rapid production check of piston gudgeon pin bores. Each pair of jets is independent and measurement of each bore on a dual air controller is simultaneous, thus giving an immediate check for parallelism.

Hand snap gauge

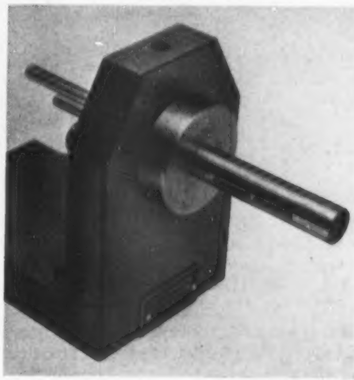
For measuring work while mounted in the machine or parts of an unwieldy size, this Solex hand instrument can furnish the accuracy usually associated with a bench-type comparator. Made in three sizes, to an overall capacity of 4·0 in, each uses the same size comparator unit and the same air controller jet and scale. Common to all are the measuring range of 0·0045 in, sensitivity to 0·00004 in, minimum length of work to be measured 0·4725 in, minimum distance of measuring point from end of work (whether flanged or not) 0·355 in and maximum length of hose connection to controller 5 ft.

To measure accurately, the gauge must, of course, be applied perpendicular to the generating lines of a cylindrical part. This is facilitated by the provision of an accurately flat anvil plane and a spring-loaded sleeve enshrouding the probe. The sleeve has a movement of about 0·02 in and the positioning pressure is independent of the measuring pressure. Both the anvil and the probe are tungsten carbide faced.

Initial setting is made with a master or a roller gauge and the coarse setting of the anvil automatically ensures the correct loading of the positioning sleeve. Fine setting is by a knurled nut on the comparator unit. The back stop may be adjusted by sight as, since the probe has a flat face, its position is not critical.

External diameter gauges

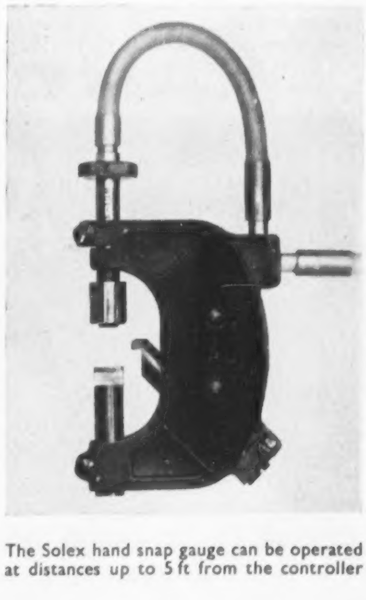
Standardized Cee-type gauges are used on a wide range of fixtures for the



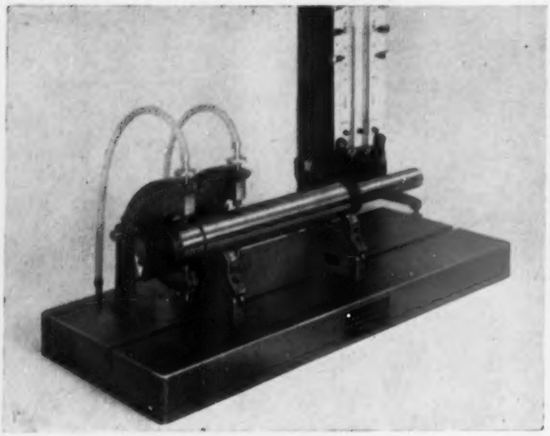
Solex plug gauge for piston gudgeon pin bores

measurement of shaft diameters. One illustrated is of the universal type for heavy-duty work and can accommodate shafts from 4·0 in to 24·0 in long. Three sizes of Cee gauge cover work of all diameters up to 4·0 in and controllers are calibrated to 0·0001 in or 0·0002 in. The roller vee work rests can be adjusted to suit various diameters of shafts. Both the rests and the gauges are laterally adjustable, the rests in a tenon slot in the base and the gauges on their support bar. Precision centres are available, enabling concentricity to be checked simultaneously with diameter.

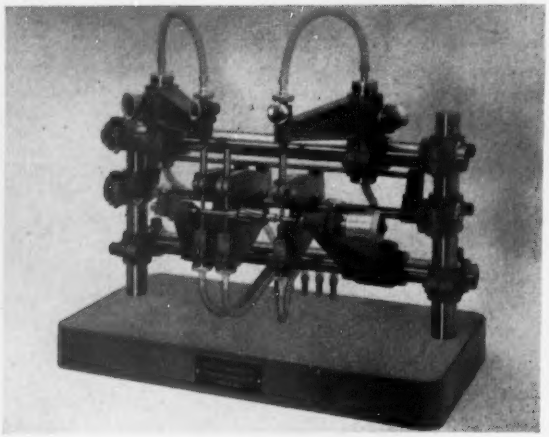
Special multiple gauging fixtures are built up from a range of standardized



The Solex hand snap gauge can be operated at distances up to 5 ft from the controller



Universal type external diameter gauge



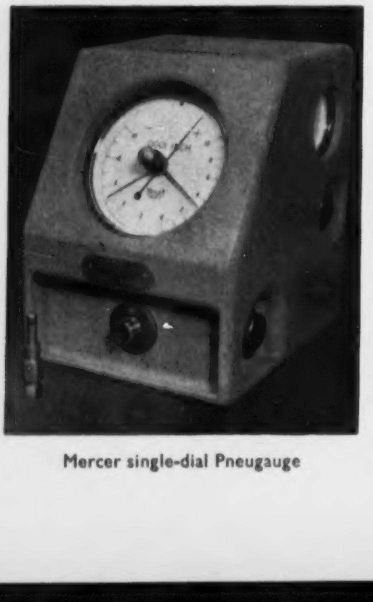
Solex gauging fixture built up of standardized components

components. An example illustrated checks the diameter of an armature shaft at three points and concentricity at two of those points. Cee gauges, centres, centre brackets, comparator units (for concentricity), comparator unit brackets, horizontal and vertical bars, and bar clamps are all standard items. Fixtures of this type can be readily adjusted or modified and are practically unlimited in their scope. Gauging fixtures having sixteen Cee gauges showing dimensions simultaneously on multi-tube air controllers have been supplied.

Solex (Gauges) Ltd., Chiswick, London.

Mercer high-pressure air gauges

A relatively high operative pressure is a feature of the Mercer air gauging system. This is claimed to ensure accuracy of reading without interference from coolant, abrasives or swarf, and a high magnification with complete stability. Indication is by means of a sensitive Bourdon tube type pressure gauge with dead-beat action on the pointer which, in conjunction with an open scale, is conducive to easy reading and speed of operation. The air supply, at pressures ranging from 60 to 120 lb/in^2, from the shop line is delivered through a filter unit to a precision regulator, the downstream side of which is held to a constant 40 lb/in^2. Satisfactory functioning of the regulator is indicated on a small dial on the right side of the instrument. Thence it passes through a variable control orifice (determining the magnification factor), the indicating pressure gauge, and a variable orifice bleed to atmosphere (for zeroing the pressure gauge) to the gauging head. Connection to the gauging head is by a flexible hose with an adaptor plugged into a socket on the front of the instrument and secured by a bayonet catch. Dimensions of a single dial unit are: height 11¾ in, width 9 in, depth 10½ in, diameter of scale 5 in, and weight 30 lb. Standard balanced scales for measuring ranges of 0·002 in and 0·004 in are read direct to 0·0001 in and for 0·050 mm in divisions of 0·001 mm, but special coloured or segmented scales can be supplied to specific requirements.



Mercer single-dial Pneugauge

Mercer Microjet plunger unit

Plug and ring gauges

For the gauging of internal or external diameters direct air jets may be used and the work does not contact the gauging element at the point of measurement. The gauging plugs or mandrels for checking bores at any axial position are furnished with two diametrically opposed balanced nozzles so that precise centring of the plug is not necessary. Average values of the diameter may be obtained with mandrels having three or more spaced nozzles. Similar considerations apply to the ring gauges for measuring cylindrical work.

Mechanical contact measuring units

To obtain a greater measuring range than can be realized with open jets, a mechanical component is interposed between the gauging nozzle and the work. In the Microjet Plunger Unit movement of the mechanical contact or probe operates an obturating device that produces a pressure change in the pneumatic system of the gauge. This change may be arranged to be greater or less than that obtained with a direct jet and thus makes possible a variation of the amplification characteristic. They are produced in standard ranges down to a minimum size of 0·312 in diameter and 1·25 in long and are conveniently incorporated in multiple gauging fixtures, machine control units and such instruments as bench comparators.

Two main types are available. Depression of the plunger in the normal-acting unit produces a pressure drop in the system while in the reverse-acting unit it effects a pressure rise.

Two-jet gauging mandrel for spline root diameter

They are intended for external and internal measurement respectively. Mechanical contacts are desirable for gauging work having either a rough surface finish or a porous surface which may tend to produce error with open jets.

Hand gap gauges

Gap gauges for external measurement embody a Microjet Plunger Unit actuated by the movable upper jaw. Special jaw forms may be used for specific workpieces and can be arranged to measure closely up to the corner of shoulders or flanges. They are readily adjustable over a range of plus and minus 0·015 in from the mean position. Jaws may be faced with tungsten carbide or hard chrome and wear can be taken up by adjustment of the measuring unit.

Gauging cross-sectional areas

For such items as metering jets or extrusion nozzles, in which the accuracy of the cross-sectional area is of greater importance than diameter or shape, the hole is used as the exit nozzle of the gauging element. A direct measurement can be taken since pressure in the pneumatic circuit assumes a value that is a function of the exit cross-sectional area. Where the area of an unrestricted hole would be outside the range of the measuring instrument, the method can still be employed by the expedient of inserting in the hole a restricting solid body of known characteristics.

Thomas Mercer Air Gauges Ltd., St. Albans.

WEAR WITH CHROMIUM PLATED PISTON RINGS

AN investigation has been carried out in the Department of Internal Combustion Engineering, Institute of Science, Bangalore-3, to determine the consequences and advisability of running high speed diesel engines on light, instead of high speed, diesel oil. A report on this work has been published under the heading "The Effect of Light Diesel Oil on High Speed Diesel Engines," by H. A. Havemann, M. R. K. Rao and A. Natarajan, in the *Journal of the Indian Institute of Science,* Vol. XXXVI, No. 2, 1954. Among the subjects that are dealt with in the paper is the effect of the different fuels on the wear of cylinders and rings when chromium plated top compression rings are fitted as well as when plain ones are used.

The engines used for the experimental work were three diesel units, the main features of which were identical, except for the combustion chambers and compression ratios. Two of them had pre-combustion chambers and a compression ratio of 19:1, the third had an open combustion chamber and a compression ratio of 16·75:1. All had the same bore and stroke and their rating was 5 b.h.p. at 1,500 r.p.m. They were run under identical test conditions but on two different fuels. One of the two engines with pre-combustion chambers was run on high speed diesel oil and the other, as well as the engine with an open combustion chamber, was run on light diesel oil. Details of the fuels are given in the table.

PROPERTIES OF THE FUEL OILS USED IN THE EXPERIMENTS

Properties	B.S. 209—1947	
	Grade A	**Grade B**
	High speed diesel oil	Light diesel oil
Sp. gr. at 75 deg F	0·84	0·87
Viscosity at 100 deg F, Redwood secs	35	45
Carbon residue, Conradson per cent weight	0·05	1·1
Sulphur, per cent weight	0·3	1·2
Water, per cent volume	nil	0·05
Sediment, per cent weight	nil	0·01
Ash, per cent weight	nil	0·01
Calorific value (lower) B.Th.U/lb	18,600	18,100

Each of the engines with a pre-combustion chamber was run for 2,000 hr, the first 1,000 hr with plain cast iron compression rings and the second 1,000 hr with chromium plated top compression rings. The engine with the open combustion chamber was run for the duration of the test, 1,500 hr, with a chromium plated top compression ring. All three were run for 16 hr per day, and six days a week.

Each day, they were first started from cold and warmed up for half an hour, and then loaded to 3·75 b.h.p. at 1,500 r.p.m. The running conditions were closely controlled and the performance of each engine was checked continuously. As soon as any deterioration in the performance was noted, the engine was stopped and the fault located and rectified.

Wear measurements were taken at the end of each 500 hr period of running. The piston ring wear was measured both by weighing the piston rings and by noting the increase in the ring gap at the lower end of the cylinder bore. Bore wear was measured on the thrust and on the non-thrust sides at depths of ½ in, 1 in, and then at 1 in intervals to a depth of 7 in, from the top of the cylinder. All three engines were run with Deusol CR 30 lubricating oil, which was changed after every 250 hr running.

Investigations showed that with Grade B fuel the rate of wear of the top compression ring was three times as great as when Grade A fuel was used. Because of the corrosion resistance as well as the abrasion resistance of chromium plating, wear of the chromium plated top rings was considerably less than that of the plain ones. Moreover, the higher melting point of chromium reduces the possibility of welding of the rubbing surfaces. Since abrasive particles or corrosive fumes were not allowed to enter the engine, the wear that took place on the top ring of the unit run on Grade A fuel was due to scuffing. The increase in wear when the Grade B fuel was employed was attributed partly to corrosion due to the sulphur content. Since sulphur combines with hydrocarbon molecules to form hard ash, it was considered that some of the increase in wear might also be attributed to abrasion.

For the first 500 hr after chromium plated top rings were fitted, the wear of the other rings was increased, but during subsequent running it was reduced. This was possibly due to the fact that chromium plated top rings take longer than plain rings to bed-in: during this period the leakage of the hot gases past the top ring increases the loading and temperature of the others. Once the top ring has bedded-in, the loading and the temperatures of the others are reduced, and so also is their rate of wear. The report states that wear of the second and succeeding rings can be reduced by using a top compression ring with a ½-1 deg taper and lightly lapping it to produce a narrow land of contact at the lower edge.

For the first 500 hr of running there was no reduction of the rate of wear of the cylinders when a chromium plated top ring was fitted. Possibly this was because the top ring had not bedded-in properly. After a further 500 hr there was a distinct reduction in the rate. One explanation given for this reduction is that at the end of each stroke, when metal-to-metal contact occurs, extremely small quantities of metallic chromium are transferred from the ring surface to the cylinder wall. The transferred material adheres with great tenacity and protects the soft underlying material from abrasive wear and corrosive contact.

PERFORMANCE PREDICTION

A Graphical Method for the Determination of Vehicle Acceleration

J. L. Koffman, Dipl. Ing., M.I.Loco.E.

PREDICTION of the speed-time and speed-distance performance of projected vehicle designs is of utmost importance. This follows from the fact that the reason for the introduction of new public service vehicles and trucks is generally to improve the operating characteristics, that is, to reduce expenses and increase schedule speeds. Foreknowledge of the performance of omnibuses is particularly desirable because sweeping and conflicting statements, made from time to time, of b.h.p/ton values have tended to cause confusion.

Usually recourse is taken to the determination of speed-time and speed-distance curves on an analytical basis, i.e., the step by step determination which, though accurate, is rather tedious and time consuming. By adopting graphical methods, the time required for obtaining the data can be appreciably reduced without unduly affecting the accuracy of the results. This enables manufacturers and operators to analyse more readily the performance of existing and prospective vehicles.

The simple procedures described in this article are based on the methods developed by Desdouits-Lomonossoff and Lipetz-Strahl[1]. The actual data worked out in the examples relate to a single-decker bus weighing 10·75 ton fully laden, powered by a 130 b.h.p. engine and with a frontal area of 72 ft². It is assumed that the loss in efficiency through the four speed transmission is 15 per cent. Tractive effort and resistance curves for the vehicle running on a smooth road are plotted in Fig. 1. The excess tractive effort available for acceleration and negotiating gradients is shown by the shaded area. From these curves, values of excess tractive effort available are replotted in lb/ton, and the method of determining graphically the acceleration that can be obtained on the level and up various gradients can then be considered.

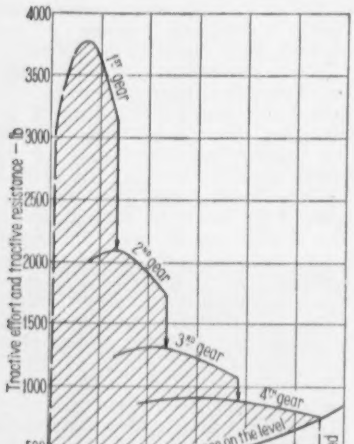


Fig. 1. Tractive effort and resistance of full-front, 10·75 ton single-deck omnibus $R = W(17+0{\cdot}2V) + C_d \times 0{\cdot}26 \times A \times (V/10)^2$
Where R = Tractive resistance, lb
W = Vehicle weight, ton
V = Vehicle speed, m.p.h.
C_d = Drag coefficient = 0·8 for full front single-deck bus
A = Total frontal area, ft²

Although it is usual to adopt ft, lb and sec as the units for the calculations, velocity, acceleration and weight are generally better appreciated by operators if expressed in m.p.h., m.p.h/sec and tons. Therefore, constants C and K for conversion purposes are derived as follows:

(1) Velocity in m.p.h.,
$V = (3{,}600/5{,}280)\ v = v/1{\cdot}467$, where v = velocity in ft/sec.
The conversion constant C therefore is $1/1{\cdot}467$.

(2) Acceleration in m.p.h/sec.,
$a = f/1{\cdot}467$, where f = acceleration in ft/sec², and to convert weight in lb units to mass in ton units, the factor $32{\cdot}17/2{,}240 = 1/69{\cdot}5$ can be used.

The conversion constant K therefore is $(1/1{\cdot}467)(1/69{\cdot}5) = 1/102$.

The fundamental equation of the motion of a vehicle is

$$(M + \Sigma I/\rho^2)\ v dv = (T-R)\ ds \quad \ldots.(1)$$

where M is the mass of the vehicle, I is the polar moment of inertia of each rotating part around its axis, ρ the relevant radius, v the instantaneous speed, dv the differential of speed, ds the elementary distance, T the tractive effort and R the tractive resistance. This equation is simplified by adding $\Sigma I/\rho^2$, which has the dimension of mass, to the total mass of the vehicle. For buses and trucks this is covered by a factor γ amounting to 5 to 10 per cent of M, so that K = 1/(102 multiplied by 1·05 to 1·1) = K′ = say, 1/110. Since v = ds/dt, equation (1) can be rewritten:

$$dV/dt = (T-R)/110M \quad \ldots\ldots\ldots(2)$$

where V is in m.p.h., t in sec and dV/dt acceleration in m.p.h/sec. Introducing the specific tractive effort t and specific resistance r, both in lb/ton of vehicle weight:

$$dV/dt = (t-r)/110 \quad \ldots\ldots\ldots\ldots(3)$$

In the following, t_{el} is the excess tractive effort available on the level, and is equal to t—r. The curve shown in the lower part of Fig. 2 is a plot of the speed-time dependence of a vehicle

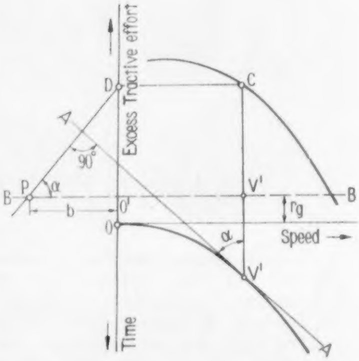


Fig. 2. Relation between tractive effort and speed-time curves

accelerating under the influence of t_{el} in one gear. Then the tangent AA to the speed-time curve at an arbitrary point V′ determines the angle α, since

$$\tan \alpha = (dV/dt)\ (a/m) \quad \ldots\ldots\ldots(4)$$

where a is the scale for speed and m the scale for time. By substituting the value of dV/dt from equation (3):

$$\tan \alpha = [(t-r)/110]\ [a/m] \quad \ldots\ldots\ldots(5)$$

The value of additional tractive resistance r_g, due to gradient, is shown by a horizontal line BB. A vertical line is drawn from point V′ on to the speed-time curve to meet the excess tractive effort curve at point C, then a horizontal line is projected on to the ordinate, which it meets at point D. From this point a line drawn at right angles to AA intersects line BB at P, and the angle α is given by DPO′. Consequently,

$$\tan \alpha = (t-r-r_g)\ c/O'P \quad \ldots\ldots\ldots(6)$$

where c is the scale for excess tractive effort.

From this it follows that by determining the position of the pole P, as given by O′P = b = constant, and connecting this point with a point C, which signifies excess tractive effort for a range of speeds (say 12·5 m.p.h. as a mean for 10 to 15 m.p.h.), the acceleration within this speed range can be obtained. This acceleration is given by the tangent to the time-velocity curve, which is perpendicular to DP. The value of O′P = b is of fundamental importance and is obtained by eliminating tan α from equation (5) and (6) so that:

$$a/100m = c/O'P$$

Consequently,

$$O'P = b = 110\ c\ m/a \quad \ldots\ldots\ldots\ldots(7)$$

Alternatively, it can be shown that:

$$b = 110\ a/m\ c \quad \ldots\ldots\ldots\ldots\ldots(7a)$$

Thus, the procedure is as follows, Fig. 3: plot the values of t—r versus vehicle speed V to suitable scales; then

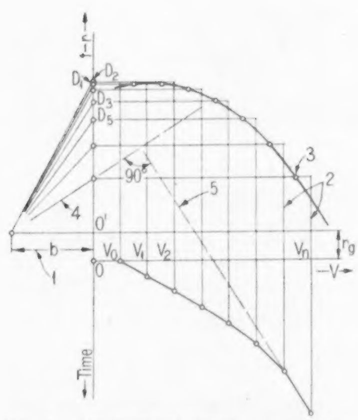


Fig. 3. Method of plotting speed-time curves

1. Determine the value of b and enter it on the t—r versus V plot.
2. Divide the speed range into suitable intervals, about 5 m.p.h.
3. Mark a point on the tractive effort curve, halfway between the limits of each speed interval.
4. Connect this point with the point determined by b.
5. Extend a line at right angles to the line obtained in 4, until it intersects with the limits of the relevant speed interval. This line represents a section of the time-velocity curve. The operations 3-5 are then repeated for each speed interval and the resultant sections of the time-velocity curve joined to produce a continuous line.

An actual plot for the 10·75 ton omnibus is shown in Fig. 4. The scales for the full size chart were chosen as follows:

$a = 10$ m.p.h. $= 1$ in, or
1 m.p.h. $= 0{\cdot}1$ in
$m = 20$ sec $= 1$ in, or 1 sec $= 0{\cdot}05$ in
$c = 25$ lb/ton $= 1$ in, or
1 lb/ton $= 0{\cdot}04$ in.

Thus, from equation (7),

$b = 110 \times 0{\cdot}04 \times 0{\cdot}05/0{\cdot}1 = 2{\cdot}2$ in

and from equation (7a),

$b = 110 \times 10/20 \times 25 = 2{\cdot}2$ in.

The time required for each gear change is assumed to be 2 sec, and the speed at the end of this interval is determined in accordance with equation (2), as follows:

$$V_2 = \frac{1000WV_1 - 35{\cdot}32(r' \pm s) \times W \times t}{1000W + 35{\cdot}32r'' V_1 \times t}$$

where V_1 and V_2 are the speeds in km/hr at the beginning and end of the gear change respectively, W the vehicle weight in tonnes, t the time in sec required for the gear change, r' the rolling resistance in kg/tonne, r'' the air resistance in kg/tonne, s the gradient $^0/_{00}$ (per thousand). Air resistance r'' is obtained from the formula $r'' = C_d \times 0{\cdot}005A$, where $C_d =$ the drag coefficient (in this case $C_d = 0{\cdot}8$), and $A =$ the frontal area in m^2. The distance travelled during the gear change is given in metric units by:

$$l = \frac{1000WV_1 - 17{\cdot}66(r' \pm s) \times W \times t}{1000W + 17{\cdot}66\, r'' V_1 \times t} \times \frac{t}{3{\cdot}6}$$

During acceleration the distance covered is determined by the area under the curve and this can be evaluated by the usual methods of counting the squares or by planimetering. On the other hand, it is possible to derive the speed-distance curve from the already available speed-time plot. However, since this method is somewhat cumbersome, it is advisable to plot speed-distance separately.

If the distance S in m.p.h. is the independent variable, equation (1) can be written:

$$(M + \Sigma I/\rho^2)(v\,dv/ds) = T - R$$

or

$$\frac{dv}{ds} = \frac{T - R}{M + \Sigma I/\rho^2} \times \frac{1}{V} = \frac{C_1(t - r)}{v} \quad ..(8)$$

Since the speed is in m.p.h.,

$C_1 = 3600 \times K' = 32{\cdot}7$, and

$dv/ds = 32{\cdot}7\,(t - r)/v$ ....(9).

In Fig. 5, in which the excess tractive effort is plotted against speed, again the speed axis is divided into a number of intervals and lines are drawn to connect the mean value of the tractive effort of each interval, D_1, D_2, D_3, etc., with O′. By plotting a section ab″ on a line at right angles to O′D_1, from b″ a section b″c″ at right angles to O′D_2, and etc., the curve ab″c″ can be drawn to represent the dependence of

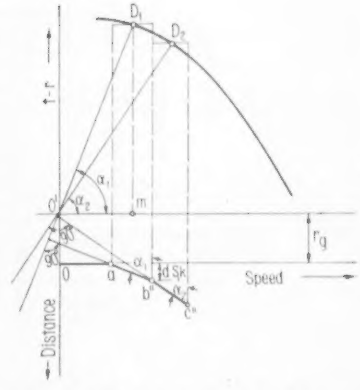


Fig. 5. Method of plotting speed-distance curves

distance covered upon vehicle speed. The triangle O′mD_1 represents for the first section:

$$\tan \alpha_1 = \frac{(D_1 - r_g)c}{v_{1m} \times a} \times 32{\cdot}7 \quad ....(10)$$

where, as before, c is the tractive effort scale, a the speed scale, r_g the tractive resistance additional to that encountered by the vehicle on level road and v_m mean speed in the range concerned. But, since

$D_1 - r_g = dv_1/dt_1 = (dv_1/d\,S_1)\,v_{1m}$ (11)

by eliminating $(D_1 - r_g)/v_{1m}$ from equations (10) and (11):

$\tan \alpha_1 = (dv_1/d\,S_1)\,(c/a)\,32{\cdot}7$....(12).

If the section ab″ represents the dependence of the distance covered upon the speed in the first interval of the curve, then the following requirements must be met:

$\tan \alpha_1 = (dv_1/d\,S_1)\,(a/k)$ ....(13)

where k is the scale for distance in miles. By equating the right-hand sides of equations (12) and (13),

$32{\cdot}7\,c/a = a/k$ ....(14)

so that finally:

$k = a^2/32{\cdot}7\,c$..................(15)

In the case considered here, $a = 10$ m.p.h. $= 1$ in, and $c = 25$ lb/ton $= 1$ in, so that $k = 10^2/32{\cdot}7 \times 25 = 0{\cdot}1225$ miles/in.

The resultant plot for the vehicle accelerating from standstill on the level as well as up a gradient of 1 in 50

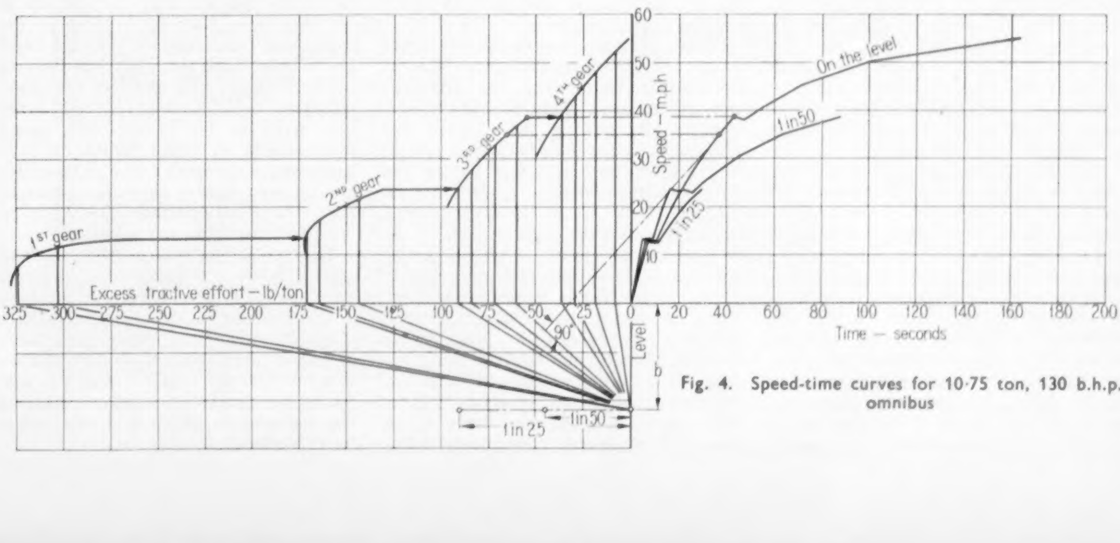


Fig. 4. Speed-time curves for 10·75 ton, 130 b.h.p. omnibus

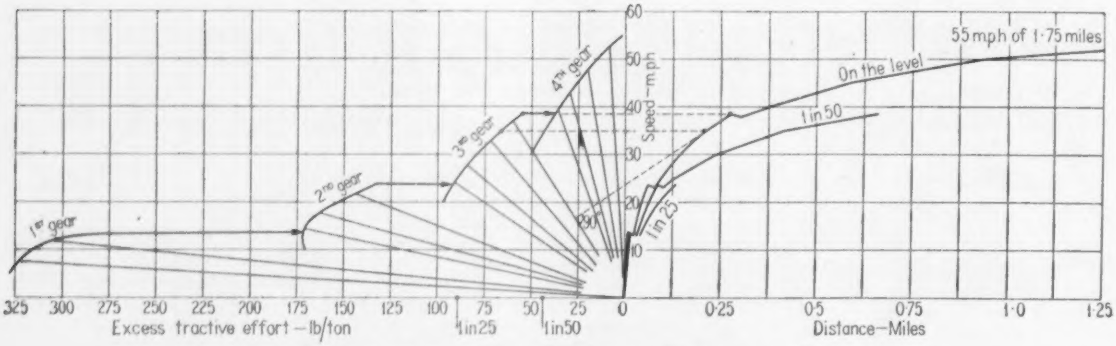


Fig. 6. Speed-distance curves for 10·75 ton, 130 b.h.p. omnibus

and 1 in 25 is shown in Fig. 6. To obtain accurate results, the speed intervals must be kept small, particularly at higher speeds where t—r tends to become smaller and the intersecting lines form acute angles so that the intersection points are not easily defined. Even so the plots can be laid out without difficulty.

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FULL SCALE LAYOUT

Lithographic and Photographic Reproduction

METHODS used in the new London drawing office of Tiltman Langley Laboratories Ltd. for the preparation of full-scale layouts for the aircraft and boat-building industries, are of interest because they might be used to advantage in a limited range of applications in the motor industry. One application might be to the manufacture of tools for the production of riveted chassis frame parts for commercial vehicles. Tiltman Langley Laboratories Ltd. are research engineers, of Redhill, Surrey, and their London office is at 70-71, New Bond Street, W.1.

Some of the advantages of the system are as follows. The tool makers have no marking out to do, so tooling costs are reduced. Tools made for components to be manufactured under sub-contract are produced from the same layout drawings as those for the main components so there is less chance of parts not matching exactly on assembly. Moreover, tools for production of detail fittings can be made from the layouts instead of from separate detail drawings.

In the lithographic process, the initial layout is drawn in cellulose ink on a *layout plate,* which is an aluminium plate with a grained surface. For certain applications, flange developments and angles, and other information not usually given on a drawing of this type, are shown. When the drawing is ready, the plate is *inked-up* by the following process. First the plate is washed with a dilute acid and then rinsed. Next, the surface is moistened uniformly; the grain of the plate holds the water and the inked lines repel it and remain dry. Then a roller, charged with either printing or transfer ink, is applied to the plate. The wet surface repels the ink but the lines do not. In this state, the plate is ready for application to the *jelly.* After application, the plate is cleared of ink and the surface protected by a film of water-soluble varnish or gum. This process is called *gumming-up.*

The jelly, or transfer plate, is a sheet of either celluloid or aluminium with a thick film of gelatine-based printers' composition on one side. It is placed over the layout, on to which it is pressed either by direct pressure or by passing the two plates between rolls. This transfers the image to the gelatine-based film on the jelly, which absorbs the ink from the layout. The jelly can be cleaned after use by wiping off the impression, and is then ready for the next application.

When the image has been transferred to the jelly, it is ready for application to the material on which a reproduction is required. This reproduction is obtained by placing the jelly on the material and applying pressure. Several impressions can be taken before the jelly requires *charging* again. Reproduction can be made on to almost any material with a flat surface.

If the image is to be transferred to metal, it is sometimes necessary first to apply to the metal a coating of matt paint to hold the ink and obtain good contrasts. By dusting the lines with a metallic powder that will adhere to the ink, good contrasts can be obtained without coating the material. Timber with an open grain may have to be prepared by filling, particularly if fine lines are required. For application to components that undergo considerable handling, a protective coat of clear varnish may be needed to preserve the image. Linen or paper, of course, can be printed and used to obtain further copies by the normal methods.

If a print is to be made on to another grained plate, for instance, to transfer contour lines on to a plate to be used for a frame layout, inert ink is used instead of printers' ink. This gives an impression that can be seen easily but which will not ink-up with the new layout.

For the production of a tool for the manufacture of a flat plate with flanged edges at an angle larger than 90 deg, two lines are drawn representing the profile. One is the bend line, and the other is the edge of the flange. Subsequently, the material is trimmed to the line representing the edge of the flange and then chamfered to the bend line where it is radiused. Impressions for drilling jigs can be taken by inking only the areas adjacent to the holes that have to be drilled and taking impressions on small jellies. In the same way, impressions can be taken for the manufacture of tools for brackets, etc., which are drawn in detail on the layout of the complete assembly.

Instead of the lithographic method, photographic reproduction can be employed. The original drawing is prepared in pencil on a sheet with a white, matt surface. Aluminium sheet is usually used. This drawing is photographed and the negative image is projected on to the sensitized surface of the material on which it is required to be reproduced.

INVESTMENT CASTINGS

Repetition Production of High-Precision Work at the Napier Foundry

ONE of the oldest arts of civilization is the casting of metals and its origin is lost in the dim ages of pre-history. It must have long been practised before the relatively advanced technique of forming a mould around an expendable pattern of wax could have been used in ancient China. This so-called "lost-wax" method of casting has been re-discovered in different parts of the world at various periods of history. It has been used by early inhabitants of the Indian continent, by European sculptors of the middle ages and in more recent times by American dentists.

The advent of the aircraft gas turbine gave rise to a demand for enormous quantities of airfoil-section blades of meticulous accuracy of shape and dimension for the compressor and the turbine. These are made in a number of different materials and by a variety of methods. Certain blades, particularly those for the nozzle ring or the stators of the turbine, could be produced economically in relatively intractable heat-resistant steels or alloys by the lost-wax or, as it is now termed, the "investment" method. As a consequence, the process has been intensively and rapidly developed with the aid of modern research and test facilities and, in view of the quantities required, is today to some extent mechanized.

The technique differs basically from that employed for the usual sand-mould casting, requires different materials and equipment, and cannot conveniently be allied to an ordinary foundry. It is best applied, as in the Napier foundry at Park Royal, London, W.3, in a separate, specialized, and completely self-contained organization. In addition to producing turbine blades this foundry also serves a number of industries, supplying small parts for such diverse equipment as sewing machines, milking machines, fuel pumps, hydraulic gear, surgical instruments, automobiles, and metal-working tools.

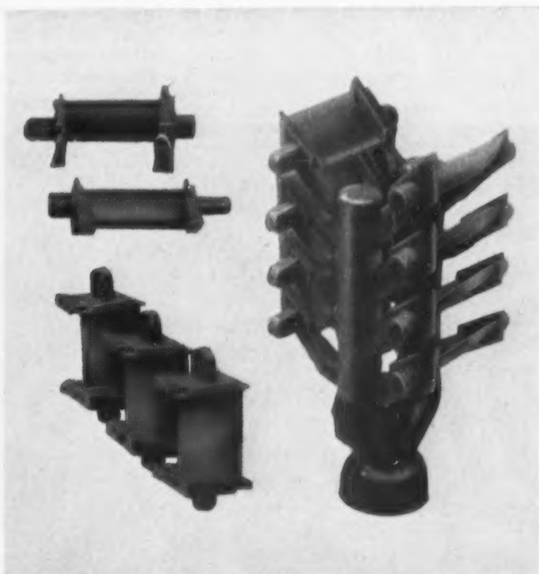
Range of application

As with other production methods, the limits of application cannot be closely defined. In general, small castings up to about 5 lb in weight, of relatively complex form and requiring an average amount of machining, can be produced economically by the investment process in numbers ranging from a few dozen to several thousand off. Where the part is very small or unusually intricate, or where considerations of shape or material render machining operations difficult, costly or time-wasting, the advantage offered by investment castings can be substantial. Castings of simple shape exceeding 10 lb in weight or required in quantities of several hundred thousands can usually be produced more economically by other methods.

Machining and finishing costs can often be lowered by the introduction of investment castings into current production but the greatest advantage is secured when they are included in the basic design of a new project. By their use instead of sand castings, die castings, or forgings, not only is machining reduced but the cost of steel dies is eliminated. The relatively simple tooling required for an investment casting can be completed in much shorter time than is usually required for steel dies. Where, after experiment or development, a part is found to need modification or redesign, the simple pattern and soft-metal dies can be modified or replaced at much lower cost, in time as well as money, than can steel dies. These factors are of outstanding value for projects in which extensive development testing or field trials must be completed before regular production can be commenced.

In full production the wear on the dies for making soft wax patterns is much less severe than is experienced on steel dies used for direct metal pouring. The original precision can thus be held for very much longer runs. When the dies do eventually wear, they can be quickly replaced from the original master pattern. In fact, as soon as the results of wear are detected, a new die can be made at relatively low cost and production need not be interrupted. Improvements to standard components made necessary by production experience, performance in service or by pressure of competition can be rapidly and cheaply effected and the product kept efficient and up-to-date

Soft-metal die for turbine blade pattern



Individual patterns, assembled cluster, and group of castings

Typical small components cast by the investment process

with a minimum of interruption.

The major production economy, however, is to be found in the reduced amount of machining required to finish a component. Dimensional accuracy and surface finish of an investment casting are such that usually a number of machining operations can be eliminated. The outlay for machines and tools is less, production time is cut, the percentage of rejects is decreased and the risk of losses arising from production breakdown is lowered.

Not only can investment castings, in suitable applications, effect substantial economies in production but they allow considerably more freedom than is otherwise possible in design. Small, complex components that, because of casting or machining difficulties, hitherto had to be assembled from several small machined parts, can often be made relatively cheaply by a single investment casting. There is virtually no restriction on shape and even multiple re-entrant contours can be cast without difficulty.

Castings can be made in a wide range of metals, including such alloys as HRCM, Stellite and HSS. If required, sections as low as 0·015 in thick can be cast and rapid changes of section thickness can be arranged with the minimum graduation necessary to avoid stress concentration. Usually the castings are finished by shotblasting but a satin finish is also available and the fine grain finish obtained by vapour blasting can be specified.

Investment casting is carried out in four main stages: (1) the construction of a metal die of the part to be cast; (2) the forming of expendable wax patterns from the die; (3) the construction of refractory moulds from the wax patterns; and (4) the pouring of molten metal into the moulds.

Die-making

Dies for the production of the wax pattern are made by various methods to suit different types and sizes of castings. The preferred and most widely used method is to make an oversize master model in aluminium and cast a die from it in a tin-bismuth alloy. Allowance must be made on the model for two shrinkages, of the wax pattern and of the mould, but none is necessary for the tin-bismuth die. An overall contraction allowance is made for each dimension on the finished drawing, but this is largely empirical and is modified from experience.

In one half of a cast iron die box the model is supported in plaster up to the desired parting line. Over the projecting portion of the model is laid a thin sheet of rubber latex, which has overlapping margins that are sealed to the outside of the die box. The other half of the box is placed in position, located by box dowels. Then the assembly is seated on rubber on the pouring table, which is so connected with a vacuum pump that, through an orifice in the table and small holes in the plaster, air trapped beneath the latex sheet can be exhausted and the latex consequently pressed tightly down on the model, following its contours, by atmospheric pressure.

Alongside is the heated vat containing the molten tin-bismuth alloy at a temperature of about 200 deg C and on a vertical column is a swinging arm

Stripping wax pattern from die at injection moulding machine

Wax pattern production line

supporting a large pot in which is housed a tilting ladle. The ladle is loaded with a suitable quantity of molten alloy, the pot is swung over the die assembly and clamped with rubber seals over the die box. The air is exhausted from below the parting latex, the alloy is poured, and air at about 40 lb/in^2 is applied through the upper clamping member to force the alloy into the die box. When cooled the box halves separate cleanly and a repetition of the process, with the model supported this time in the tin-bismuth, enables the other half of the die to be cast to the parting line. These soft-metal dies can be used to make thousands of wax patterns. A variation of this type is the composite die, in which an aluminium block is bored or recessed to receive a tin-bismuth lining.

Built-up dies are made by machining blocks of steel, brass or aluminium and fitting inserts or core pieces. Aluminium is preferred for ease of production and subsequent ease of handling. Only in the more exceptional instances where the model technique is impractical or the cost of fabricating a die would be excessive, is resort made to conventional die-sinking methods. For complex castings it may be necessary to make dies for a number of component parts, the waxes from which are assembled to form the complete pattern. All dies are arranged with the feed hole at a standardized height to obviate the need to reset the wax injection press when changing over from one job to another.

Wax patterns

The production of the wax pattern represents the first stage of the casting process. Two die sets are used, one being injected and cooled while the other is emptied and reassembled. On the table of an injection press the operator cleans the die parts and sprays the cavities with Teepol or Releasil to prevent the wax sticking and to ensure sharp corners on the pattern. When assembled the die is slid under the platen with the feed hole engaged over the injection nozzle. The injection cycle is automatically timed to lower the platen and clamp the die, inject the correct volume of wax, hold until the wax cools and then raise the platen.

Fusing the component parts of a wax pattern assembly

Operation is by depression of two widely spaced push buttons—a safety measure to ensure that both hands of the operator are clear of the platen. Wax is supplied from an electrically heated storage tank attached to the press and thermostatically controlled to maintain the wax at the appropriate temperature for injection. A mechanical stirring device continuously agitates the wax to ensure uniformity.

From the press the wax pattern is conveyed to another operator for inspection. In the case of complicated shapes that will not "draw" in a simple divided die, several component patterns may be produced and then assembled to form a single multi-part pattern. The respective parts are arranged for convenient location and after being mounted in position with polystyrene adhesive are joined by running a heated spatula along contiguous edges to melt the wax locally and fuse the two parts together. Either gas-heated or electrically heated spatulas are used. When completed, the dimensional accuracy of the pattern is checked and any small surface blemishes are corrected.

Small parts are commonly assembled with runners to a common sprue to form a cluster of convenient size for a standard investment flask. The assembly is weighed, and from this figure the amount of casting metal required is calculated. When castings include relatively large sections, supported "chills" of a low-grade wax may be fitted. These reduce the volume of new wax required—and consequently the cycle time—and also prevent the sinking of the pattern. Silica rods are used to reinforce thin investment cores against vibration. Sprues, chills and runners are made from reclaimed wax.

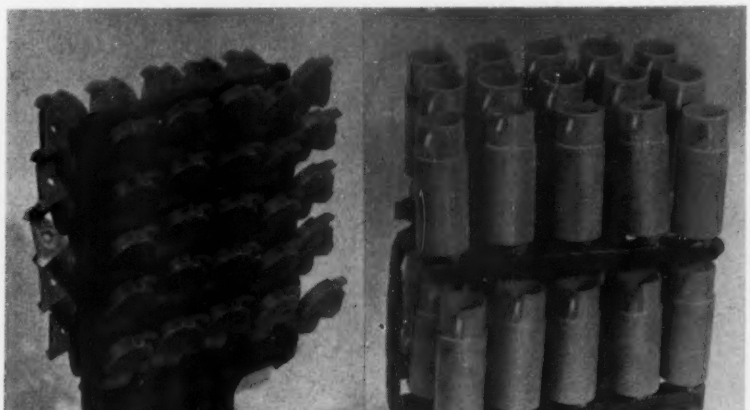
Pre-coating

From the wax assembly shop the patterns are taken by a belt conveyor to the pre-coating and investment shop. Here a fine refractory powder and a silicate solution are brought to a smooth creamy consistency in a bowl-type mixing machine. The wax pattern is dipped into this mixture, shaken to remove excess, and drained to leave a thin coating. This eventually forms the mould facing and ensures a fine surface finish on the casting. Before the coating has completely dried it is given a backing of a coarse refractory sand in a booth of a specially built machine. In this a bucket-type conveyor lifts the refractory from a base container and delivers it to a vibrating screen from which it pours over the pattern. With this adherent coating the patterns are placed in trays and allowed to air dry.

Investment

The mould is formed around the wax pattern in a standard vertically divided flask. First a loose, square baseplate with a central orifice is coated on its upper face with molten, reclaimed wax. The sprue of the pattern is stuck on the plate over the orifice with wax. When the wax has set a steel or aluminium flask, with a previously fitted lining of waxed paper, is set over the pattern and sealed down to the plate with more wax. A conveyor transports the flasks to the investing station where coarse refractory sands and a silicate bonding solution are formed into a slurry in a rotating barrel mixer.

Standing on a small vibrating table, the flask is filled with the slurry which



Typical wax pattern clusters

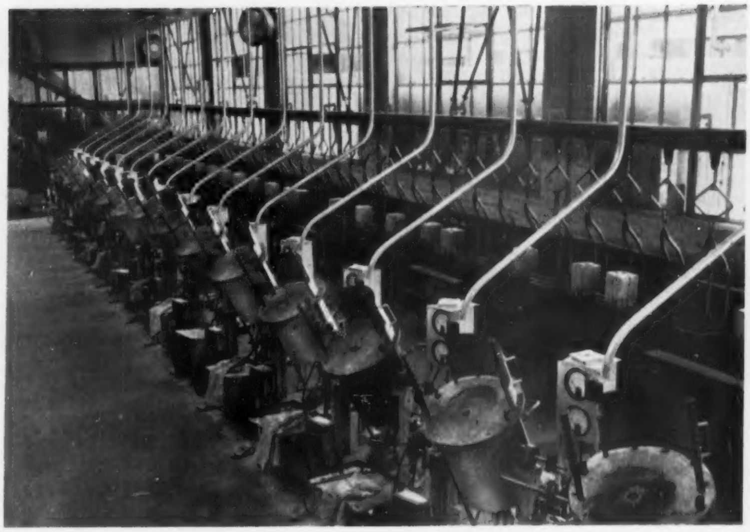
Pre-coating of wax patterns with refractory powders

Setting up the pattern in the flask

The investment stage

Loading the moulds into the firing furnace

is ladled by hand from the mixer and poured carefully down the sides of the flask to avoid damaging the pattern. In order that the flask can be overfilled to allow for settling of the investment, the waxed paper lining extends beyond the upper edge and is supported by a short extension flask of aluminium. From the small vibrating table, which disperses air from the investment, the flask is taken to a large vibrating table to pack the investment closely around the pattern. The time required for this operation is predetermined from the size, pattern type and pattern displacement and is thus varied. Commonly it is of the order of approximately 30 min. On settling, the surplus liquid rises to the top and, when the vibration is completed, is poured off. The extension flask is removed and the mould set aside to dry out. Before drying is completed the surplus head of refractory material is removed on an abrasive wheel cut-off machine, leaving the mould flush with the top of the flask. Total drying time is determined by the volume of the investment.



The battery of melting furnaces. Filled moulds are conveyed to the knock-out shop

Melt-out, stripping and firing

After drying, the moulds are placed on two-tiered trolleys equipped with collecting trays and wheeled into one of a battery of tunnel-type preheating ovens. In these a temperature above the melting point of the wax pattern is maintained and during the passage of the mould through the oven the wax runs out through the orifice in the baseplate and is caught in the tray. On leaving the oven the flask and the baseplate are stripped off and the wax in the tray is poured into a container for subsequent use as sprues and runners. All patterns are of new wax.

The moulds are immediately transferred to one of two conveyor-type firing furnaces. Each furnace has a pair of channel tracks on which independent carrier platforms run on balls. From loading to discharging ends of the furnace the temperature is progressively increased from about 150 deg C to 1,000-1,100 deg C. In the furnace any vestiges of wax remaining in the mould cavities are burnt—and the wax is specifically of a type that leaves no ash. The process of firing increases the permeability of the mould, facilitating the escape of gases when subsequently the metal is poured into it.

Four moulds can be carried on each platform and a full charge is about 250 moulds. When the moulds have been withdrawn from a platform, the unloader gives an audible signal by an electric bell to the loader who, by press button, operates a hydraulic ram which moves the charge of moulds one station through the furnace. The empty platform and the supporting balls are discharged and by means of lifting and gravity conveyors on one side of the furnace are returned to the loading end for re-use.

Casting

While the moulds are being fired the metal is being melted in a battery of tilting type, indirect-arc, electric furnaces. A rigid control is maintained on metal composition, weight and pouring temperature. The precise weight of the specified metal for each mould is issued from store in a separate tray and the job card states this weight and also the pouring temperature. An immersion thermocouple is used to check the temperature of the metal in the furnace. This instrument does not indicate locally, but on a huge dial mounted high on the wall for easy reading by the operator—and also by the chargehand and the technical controller.

The mould is lifted by tongs direct from the firing furnace and placed over the orifice of the melting furnace. Here it is secured by an air-operated clamp and the furnace is inverted to pour the metal and fill the mould. Air pressure is applied to the crucible to force the metal into the interstices of the mould cavity and ensure sharp definition of the casting. The use of a high mould temperature is essential to prevent the chilling of thin sections. While the furnace is still inverted the clamp is released and the mould transferred by tongs to a pendulum-type conveyor which travels completely around the foundry. Its rate of travel is arranged so that the mould is cold when it is delivered to the adjacent knock-out shop.

Pouring the metal into the mould clamped to the furnace

Knock-out and fettling

Since, during firing, the mould acquires a brick-like hardness, some force is necessary to break it open to release the casting. The four knock-out booths are each equipped with a spring-supported, pedal-operated pneumatic hammer. The mould is placed on a

MECHANICAL PROPERTIES AT ROOM TEMPERATURE ON TEST PIECES CAST IN THE NAPIER FOUNDRY

Spec.	Treatment	Yield ton/in²	Ult. ton/in²	Elong. per cent	Izod ft-lb	Brinell number
S.6	As cast	31·5	37·0	5·0	9·8	230
S.6	Normalized 860°C. Air	35·4	41·6	6·0	12·6	232
S.14	As cast	16·7	28·4	12·0	7·5	149
S.14	Water hardened 780°C 10 min Tempered 140°C ½ hr.	43·2	51·2	3·0	7·0	327
S.15	As cast	25·0	29·0	3·0	8·0	194
S.15	Water hardened 760°C ¼ hr Tempered 140°C ½ hr	—	32·0	2·0	8·8	277
S.28 EN.30	Air hardened 820°C ¼ hr Tempered 200°C ½ hr	69·6	91·4	3·5	—	—
S.28 EN.30	Oil hardened 820°C ¼ hr Tempered 200°C ½ hr	—	80·5	2·5	—	—
S.61 EN.56	As cast	—	67·75	2·5	6·8	400
S.61 EN.56	Oil hardened 940°C ¼ hr Oil tempered 600°C ½ hr	—	56·58	2·5	6·8	319
S.61 EN.56	Oil hardened 940°C ¼ hr Oil tempered 720°C ½ hr	—	—	—	33·1	—
S.90 EN.38	As cast	33·0	38·5	4·0	9·5	239
S.90 EN.38	Oil hardened 760°C ¼ hr Tempered 140°C ½ hr	64·7	66·0	3·5	8·3	378
S.82 EN.39	Carburized 875°C. Cooled in box Oil refined 840°C 5 min Oil hardened 780°C ¼ hr	—	68·0	3·5	15·6	385
S.82 E.N39	Oil hardened 780°C ¼ hr Air tempered 550°C ½ hr	—	—	—	10·41	307
S.82 EN.39	Oil hardened 780°C ¼ hr Air tempered 600°C ½ hr	—	—	—	17·5	278
S.82 EN.39	Oil hardened 780°C ¼ hr Air tempered 650°C ½ hr	—	—	—	26·25	238
DTD.317	Carburized 875°C Cooled in box Oil hardened 850°C ¼ hr	68·4	81·0	3·0	—	431
DTD.317	Normalized 900°C ¼ hr Oil hardened 850°C ¼ hr Air tempered 550°C ½ hr	62·5	67·0	12·0	19·37	340
DTD.317	Normalized 900°C ¼ hr Oil hardened 850°C ¼ hr Air tempered 650°C ½ hr	50·0	58·0	18·0	59·0	250
S.80	As cast	25·2	41·0	4·0	—	384
S.80	Oil tempered 780°C ½ hr	21·3	40·8	3·0	—	273
S.80	Oil hardened 940°C ¼ hr Oil tempered 720°C ¼ hr	23·5	38·9	5·0	—	246
X.40	Chrome Cobalt Alloy Aged 815°C 30 hr 0·1 per cent P.S. 32·0	34·0	47·5	13·0	—	—
HRCM	Normalized 1050°C	15–20	30–35	15·0	—	—

block of wood on a substantial grid table and, when the casting is extracted, the debris is broken up until it falls through the grid on to a belt conveyor for transfer to the reclamation plant. A large diameter suction duct in each booth continuously draws off the dust.

In this shop is also a Spenstead shot-blasting unit. Castings or clusters of castings are blasted with 30 grit steel shot to remove all adhering refractory. The work is placed in eight circular rotating trays mounted on a large revolving table which carries them into and out of the blasting zone.

Castings are then sorted into trays and transferred to the fettling shop where feeders, gates and risers are cut off on abrasive wheel machines, flash lines are removed and surface imperfections ground off. Gates on surfaces to be subsequently machined are fettled to leave from 0·005 in to 0·015 in witness.

Certain types of castings demanding a high precision—compressor and gas turbine blades are an example—are polished on emery bobs, given a dimensional check to a gauge and then a second shot-blasting. Very small items may be finished by hand filing.

Inspection

Every casting is subjected to careful inspection for quality and dimensional accuracy. Small runs may be measured with hand micrometers but repetition work is checked in fixtures equipped with dial gauges or on comparators. The inspection department is fully A.I.D. approved. Work is maintained to a high standard and castings are held to limits more commonly associated with machining processes. A comprehensively equipped X-Ray laboratory is maintained for examination or investigation of casting structure.

Materials control

All materials, metals and alloys entering the foundry are sampled and

In the knock-out shop the moulds are broken open by pneumatic hammers

Shotblasting the castings to remove adherent refractory material

Every casting is subjected to close inspection

checked in the chemical laboratory for conformity to specification. Investment solutions, received in drums, are hoisted to an elevated structure housing a battery of four mixers. Solutions of the required composition are piped to the shops in quantities measured by flow meters.

The refractory materials, generically known as "grogs", are stored in chuted hoppers and drawn off as required. All grog is passed through a vibrating screen and mixtures of various grogs are intimately blended in a cube-type mixer. A range of blends, capable of meeting the varied requirements of the foundry, has been established and these are bagged by weight for issue to the investment shop.

Reclamation of materials

The use of melted-out wax for sprues, runner gates, chills, and also for sealing flasks has already been mentioned. Broken mould material from the knock-out shop is reduced in a pug mill in the grog shop and, after screening, some proportion is mixed with the new grog for re-issue. All metal sprues, runners, cut-offs and rejected castings are collected and segregated. Two low-frequency electric furnaces, each having a capacity of 200 lb, are used for re-melting the metal, which is cast in ingots suitable for loading the melting furnaces. An analysis of the metal is made before acceptance into store and if found necessary it is re-alloyed to bring it up to specification.

S.I.R.A. GEAR

A High Efficiency Gear that, if Necessary, can be made Irreversible

IN 1946, the S.I.R.A. organization was founded in Genoa, to develop a gear system on which Alessandro Roano, of Naples, had been working for more than 30 years. World patent rights of this gear have recently been acquired by S. E. Opperman Ltd., of Boreham Wood, Herts. The system has a number of advantages and might be suitable for certain applications in automobile design.

These gears can be made in either reversible or irreversible form, and their arrangement consists essentially of a double-helical gear and pinion, the axes of which are parallel. With the irreversible type, the pinion cannot be turned by a torque applied to the wheel. The tooth section of both wheels is approximately of trapezoidal form, and its thickness at the base is relatively large, so the strength of this type of gear is greater than that of the module type. Since the helix angle, and therefore the circular pitch, of the teeth on the pinion is different from that on the larger wheel, the transmission ratio is greater than the ratio of the pitch circle diameters of the two.

Both the reversible and irreversible types have the following characteristics. More than one tooth is always in mesh. Therefore, the contact pressure is relatively low and the life of the gear is correspondingly good. During continuous running, temperatures in the gearbox stabilize at a moderate level. The gear and pinion have the same axial pitch, but the helix angles are different; nevertheless, the teeth mesh correctly because contact takes place in an area offset from the plane containing the axes of the spindles. The amount of this offset determines the degree of irreversibility.

Mechanical efficiency varies, of course, with load and speed. A reversible gear with a ratio of 1:40 and running at 2,200 r.p.m. has given an efficiency of about 92½ per cent when the power transmitted varied over the range of 8-24 b.h.p. In the low horse power and low speed range an irreversible gear with a ratio of 1:11 has given, when delivering 0·6 b.h.p., an efficiency of 71½ per cent at 112·5 r.p.m. As is to be expected, the efficiency falls off rapidly as the power transmitted is reduced below about 0·4 b.h.p. The manufacturers state that large or small ratios can be obtained with this system, and that ratios of 1:2 and even 1:1 have been obtained satisfactorily.

NICKEL PLATE

SOME details are given in the August 1954 issue of *The Engineers' Digest* of a novel nickel sulphamate plating bath process by means of which nickel coatings with special properties are produced. Applications are said to lie mainly in operations such as re-sizing worn or incorrectly machined parts, the production of heavy coatings for various purposes, and electro-forming. The hardness of the coating is claimed to approximate 600 Vickers. In spite of this hardness, internal stresses are low and there is freedom from abnormal brittleness.

The basic constituents of the bath are nickel sulphamate, nickel chloride, and boric acid. Naphthalene 1, 3, 6-trisulphonic acid can be introduced as an additive. This additive has a marked effect upon the properties of the nickel deposit, increasing its hardness, creating an internal compressive stress, and increasing its tensile strength and electrical resistivity. Cobalt and organic agents may be added to the bath to produce an almost two-fold increase in resistivity.

In salvage operations on tools, crankshafts, diesel engine cylinder liners etc., nickel is plated to thicknesses as high as from 0·03-0·05 in. The hard plate may be used either for the entire build-up or for a large proportion of build-up, the remainder being effected by chromium plating.

Electro-forming that involves plating on matrices or patterns is an important application. It is considered that the stress characteristics of the deposit and its hardness and wear resistance constitute favourable factors. The sulphamate process has been used for reproducing geometric surface roughness standards by electro-forming. Other applications include leather embossing dies and the electro-forming of wave-guides.

MACHINE REPAIR

An Interesting Application of the Metalock System

THESE notes deal with an unusual repair carried out by Metalock (Britain), Ltd., Grand Buildings, Trafalgar Square, London, W.C.2, at a large plant producing drop forgings for the automobile industry. The production plant includes a number of American type hammers ranging from 1,500 to 5,000 lb capacity, most of which first went into operation in 1940. These hammers were subjected to continuous operation on a 24 hour three-shift schedule during the war, and since the war pressure of output has remained high.

Recently, output was threatened by the appearance of fractures in the legs of several hammers. The affected hammers could not, of course, continue to function satisfactorily and the Company had to consider possible lines of action to bring the hammers back into use. They could have the hammer legs removed and sent away for welding, with a consequential delay due to dismantling, transporting and re-assembling; they could replace the fractured legs with new ones, but this again involved considerable consequential delay.

After all aspects of the problem had been considered, a decision was made to employ the Metalock process of "cold" repair. There were three reasons for this decision: time, cost and reliability. Metalock repairs are carried out *in situ*, without any dismantling; an important factor in reducing the time the machine is out of action. Furthermore, the repair could be carried out at a price well below that for replacements, which, added to the greater saving through the lessened interruption to production, made the cost element an important consideration. The reliability of the Metalock system had already been proven within the organization.

The Metalock system of repair, for which portable hydraulic equipment is used, begins with clamping the cracked section in position. A cracked hammer leg is shown in Fig. 1. Next, lines of blind holes are drilled transversely to the fracture, see Fig. 2. These act as pilot holes which are subsequently opened out to produce lines of holes across the fracture, with only a fine channel of metal between. This metal is then removed by a hand-operated pneumatic tool scoop, to give the effect shown at the top of Fig. 2. Metalock keys, identical in shape, are then driven in, one at a time, and peened into both the parent metal and the preceding keys. A key is shown above the top row of holes in Fig. 2.

It is this key system that makes it possible to restore the fractured part to the exact degree of strength and flexibility. The tensile strength of each key is known, and if the strength to be restored is ten times that of one key, the depth is drilled to take ten keys. Where the strength to be restored is great and the fracture extends over a wide area, a development of the Metalock process, Masterlock, is employed. This method was used on hammer legs where one fracture was 72 in long in metal $3\frac{1}{2}$ in thick.

The Masterlock used on the hammer legs, see Fig. 3, was calculated to take the great and concentrated stress and also to act as a shock absorber. Half-holes along the side of the Masterlock block, precisely match half-holes in the section cut out of the hammer leg. Thus, the Masterlock, when sunk flush into the cavity, combines with the edge of the parent metal to form a series of full holes. Alloy dowels are driven into these holes and peened to create a joint of proved strength and durability. The completed repair is shown in Fig. 4.

The completed repair is of a character that dampens compression stresses, distributes the load away from the fatigue point and relieves internal stresses where the cracking occurred. In addition, the alignment and original surfaces are maintained and there is complete freedom from distortion.

Two Metalock operators, working a nine-hour day, had the hammer with the 72 in fracture fully functional in seven days. Within three weeks, four operators fully restored two severely fractured hammer legs and had two more close to completion. This compares favourably with the results obtained by conventional repair processes. The time factor comparison is that whereas the Metalock repair was completed in seven days, a conventional repair interrupted production for three months; on a cost basis, the Metalock repair cost about one half of that for new castings.

Fig. 1. Fractured board hammer leg

Fig. 2. Preparation for the Metalock process

Fig. 3. Inserting the Masterlock

Fig. 4. The completed Masterlock repair

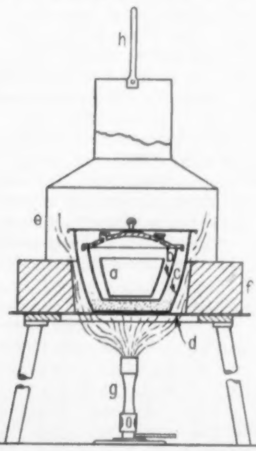
LUBRICATING OIL TESTS

A Survey of their Significance for Determining Quality

E. W. Steinitz*

IN spite of the fact that the oil companies are now very communicative concerning the properties of their products, in advertisements and pamphlets, users and the general public still have little knowledge about lubricants. The term "general public" in this context includes engine and car designers and operators of fleets of lorries, cars and transport undertakings. One of the reasons is that specialization in science proceeds further and further and the author has found that even graduated and experienced organic chemists, if they are not directly concerned with lubricants, fall victims to serious fallacies concerning lubricants and lubrication.

It is common practice in the oil trade to provide for each oil a specification table of test results and in the following paragraphs we are going, first, to discuss the significance of these test results as a basis for forming an opinion about lubricants. Later on we will discuss the possibility of assessing the quality of oils by means of short tests in the laboratory. The American Society for Testing Materials (A.S.T.M.) has published a booklet[1], already in its sixth printing, about the significance of these tests. In the following paragraphs we shall be, in general, in agreement with the A.S.T.M., although we have found it necessary to be more definite in our statements.



(a) porcelain crucible, (b) iron crucible with lead and air vent on sand layer, (c) outer iron crucible, (d) stand, (e) hood, (f) shield, (g) bunsen burner

Fig. 1. Conradson apparatus for carbon residue determination

Specific Gravity

The specific gravity relates the weight of a given quantity of oil to the same volume of water. It can be determined very exactly to the fourth decimal. In U.S.A. the A.P.I. gravity scale is still in use, which somewhat complicates matters, and this scale will, we hope, soon be discarded. The specific gravity is of importance in the control of refinery operations. A test can be made quickly and easily and it supplies information which is useful for process control. It is also very suitable when large quantities of oil are sold by weight in order to find out the volumes involved.

Everybody in the petroleum industry agrees that the specific gravity is of no value as an index of the quality or usefulness of a finished oil and that its use should be discontinued, but it still lingers on in specifications. Some consumers refer to "heavy" and "light" oils respectively, or oils with or without "body," but the author has the feeling that they, in fact, refer to the viscosity rather than to the gravity.

Ash content

As a matter of fact there is no standard method for determining the ash content of oil and it is hard to explain why it still finds its way into specifications. A matter of 50 or 60 years ago some oils that were not properly treated after passing through fuller's earth in the refining process contained a percentage of mineral matter and this was, of course, detrimental as far as preventing friction was concerned. For many years past such a condition has been considered impossible. On the other hand, used or reclaimed oils have to be analysed sometimes for ash. All that is necessary for ash determination is to weigh a quantity of oil, burn it carefully and then ignite the residue at white heat.

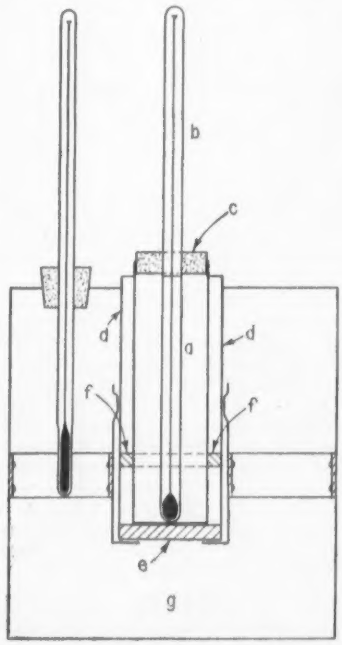
It is interesting to note that to-day for quite a wide range of oils a high ash content can mean high quality, since it is an indication of high additive content. Many basic oils of present manufacture are unsuitable for internal combustion engines without the inclusion of additives, most of which are metal compounds that leave an incombustible residue.

Carbon residue

There are two different methods, the Conradson and the Ramsbottom, in use for investigating the carbon-forming properties of motor oils. They are rather similar to each other in principle. Conradson equipment is shown in Fig. 1. It can be seen at once that the appliance is rather crude and useless for the purpose of examination of an oil as it does not reproduce the conditions in an engine cylinder. To quote the rather carefully worded A.S.T.M. statement: "Under ideal conditions the carbon produced would perhaps be proportional to the deposits in the cylinder but the viscosity of the oil, the mechanical condition of the engine and the conditions of carburation of the fuel may dominate in controlling carbon deposition." The author has found that excellent oils with long and successful records in engine lubrication show a high carbon residue by this test, while quite unsuitable oils, on the other hand, show no Conradson carbon at all.

Cloud and pour point

Again, as in the case of carbon residue, the standard method prescribed by A.S.T.M. and the Institute of Petroleum is rather crude, see Fig. 2. The instruction says that the oil contained in the flat bottom test tube shall first be observed for the start of cloudiness. This condition is due to the formation of a paraffin crystal lattice within the oil and the temperature at which it occurs is the cloud point. Then the test tube is to be taken out of the bath every few minutes and tilted in order to determine whether the oil still flows. If it does not, the pour point has been reached. From this it is clear that the test is quite good for finding out whether an oil can be handled and



(a) flat bottom test tube, (b) thermometer, (c) cork, (d) holder, (e) cork disc, (f) ring gasket, (g) tank for freezing mixture

Fig. 2. Apparatus for cloud and pour test

*Automobile and Industrial Research Station of C.R. Laboratories Ltd., London, N.12.

Fig. 3. Steiner rolling sphere viscosimeter, double-walled design, for rapid determinations at low temperatures

poured in the open air at frost temperatures from tanks into canisters and can be filled into engines. The test is absolutely unsuitable for what we want to find out, which is whether the oil would allow the electric starter to crank the engine fast enough for firing. If the oil is too viscous the engine does not fire and the battery suffers damage. In order to ascertain whether an oil is suitable for use in frost temperatures, it is far more important to know the viscosity at a given low temperature. This, and not the pour point, should be stated in each case of sales and supplies.

In his own work the author has found that many oils do not show a cloud point since they do not develop a paraffin lattice. Furthermore, it has been found that some oils with a low pour point are very bad for starting whereas other oils with a pour point above the freezing point of water can be used far below their pour points. Incidentally, the pour point test gives very different results according to what is called the thermal history of the oil. This means that an oil behaves very differently when it is cooled down in its virginal state as opposed to the case where it has already been heated and cooled repeatedly.

Viscosity

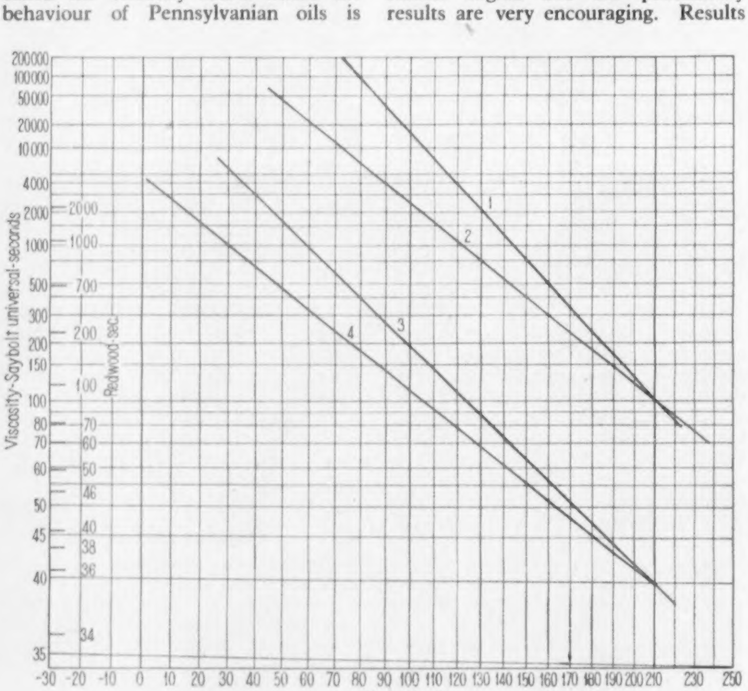
For all lubricating oils viscosity is the most important single property. It is a measure of the flow resistance of a liquid or the resistance against the movement of the particles. The unit of viscosity for international scientific purposes is the centistoke, whereas in the different countries different practical units are still in use. In commercial work viscosity is usually expressed in seconds of time for a given volume of liquid to flow through an orifice. This is true of the Saybolt (U.S.A.), Redwood (Great Britain) and Engler (continental Europe) viscosimeters. All these instruments have the drawback that they work impossibly slowly at frost temperature where, as we have seen, it is most desirable to know the viscosity. Unfortunately, no viscosimeter has been standardized so far for work at these temperatures, although some very good ones are on the market. Fig. 3 shows a very good instrument for this purpose.

It is most important to know the viscosity at the temperature at which the oil is to be used. All liquids, and mineral oils in particular, change their viscosity to a very high degree with temperature. Mostly the viscosity is stated for 70, 140 and 200 deg F respectively. The A.S.T.M. viscosity temperature charts for liquid petroleum products, Fig. 4, permit the extrapolation or interpolation of viscosities at any temperature from the measured viscosities at two or three temperatures, although the extrapolation to low temperatures is somewhat uncertain.

Tests show that many oils on the market are viscous enough at the temperatures obtaining in the circulation system and are, on the other hand, frost-proof. They have a good viscosity temperature curve and with such oils it is quite unnecessary to change the grade at the beginning of summer or winter. The slope of the temperature viscosity curve is measured by what is called the viscosity index where the behaviour of Pennsylvanian oils is marked by viscosity index 100. For all detailed computations and mathematical discussions the reader will be advised to consult the text and reference books. If a fluid film separates the surfaces of a bearing (full fluid friction) the viscosity of the oil at the operating temperature and pressure is the property which determines bearing friction, heat generation and the rate of flow under given conditions of load, speed and bearing design. In this connection the system: piston/cylinder wall/piston ring can be looked upon as a bearing, and in general fluid friction will occur on this point. On the other hand, many conditions on the cylinder wall are still obscure in spite of intensive research during the last 45 years.

In a circulation system of a vehicle engine, the temperature will never be higher than 210 deg F and on the cylinder wall the temperature will be about the same no matter what the atmospheric temperature. The viscosity of an oil at 210 deg F should not be below 40 sec Redwood. The popular oil grades are mostly somewhat more viscous than that. If the viscosity is too low, half fluid friction and excessive wear will occur. With too high a viscosity there will be power loss. Oils to be used in winter should not have a higher viscosity than 40,000 sec Redwood at 0 deg F.

There is still a tendency to select oils of high viscosity since it is thought that they are more favourable. The author at the moment is running a test with an oil of very low viscosity on an A70 Austin engine and the preliminary results are very encouraging. Results



No. 1. S.A.E.30 oil, viscosity index approx. 80
No. 2. S.A.E.30 oil, viscosity index approx. 100
No. 3. S.A.E.50 oil, viscosity index approx. 80
No. 4. S.A.E.50 oil, viscosity index approx. 100. This oil is frost-proof

Fig. 4. Viscosity-temperature chart

to date show a surprising increase in power with reduced petrol consumption.

During the last few years it has been more and more popular to buy and sell oils according to S.A.E. numbers. This designation stems from a table published by the Society of Automotive Engineers (U.S.A.) and it might be helpful to show this table with the viscosities converted into Redwood seconds.

CRANKCASE OILS

S.A.E. Viscosity Number	Viscosity Range At 0 deg F		Redwood seconds At 210 deg F	
	Min	Max	Min	Max
5W	—	4,200	—	—
10W	*5,000	10,000	—	—
20W	†10,000	40,000	—	—
20	—	—	40	50
30	—	—	50	60
40	—	—	60	73
50	—	—	73	94

*Minimum Viscosity at 0 deg F can be waived provided viscosity at 210 deg F is not below 36 sec Redw.

†Minimum Viscosity at 0 deg F can be waived provided viscosity at 210 deg F is not below 40 sec. Redw.

TRANSMISSION AND AXLE LUBRICANTS

S.A.E. Viscosity Number	Viscosity Range Redwood seconds	Consistency: must not channel in service at
80	85,000 at 0 deg F max	−20 deg F
90	675 to 1,275 at 100 deg F	0 deg F
140	105 to 170 at 210 deg F	35 deg F
250	170 at 210 deg F min	—

Flash point, fire point and heat resistance

The flash point is the temperature at which mineral oil products produce gas inflammable enough to be ignited by a small flame brought near the surface. Flash point determinations were introduced in order to judge the fire risk in storage and transport of burning oil (paraffin), petrol and other products. For lubricating oils which have a flash point well above 300 deg F the Marcusson apparatus is in general use (open cup). Although the method is again rather crude, the results are satisfactory.

For assessing the quality, and in particular the heat resistance, of a motor oil the flash point has no significance at all. Again, the fire point, that is, the temperature at which the gases continue to keep alight, also has no significance. In spite of this many consumers still buy by "flashpoint." This is not only wrong but can have the opposite of the desired result. With compressor oil in particular many consumers are of the opinion that the oil with the higher flash point provides more safety against explosions and self ignition. We can only mention in passing that all principal conditions being equal, the oil with the higher flash point has a lower auto-ignition point. Compressor explosions are never caused by self-ignition of the oil.

Acidity

In the minds of consumers, and in particular of works chemists of many companies, the acidity of lubricating oils plays an important role. There is some hazy belief that an oil which may contain acid even in traces will cause corrosion of machine parts. It must be stated quite emphatically that no oil, no matter which refinery supplied it, will contain any acid of such description as to produce operational difficulties.

The acid content of a lubricant is expressed as acid number or neutralization number. Neutralization number of below 0·1 means practically an acid-free oil. The A.S.T.M., furthermore, points out that it is still a habit in some quarters to express the acid content "computed as sulphur dioxide." They discourage this because it has been found that some consumers assume, in error, that an oil in such a case may contain sulphur compounds that are definitely detrimental.

It has been shown in practice that a content of organic acids in oil is not at all detrimental and several important oil companies used purposely to add olic acid to their mineral oils. In fact such oils showed very good properties for many uses. All oils develop a content of organic acids in the process of ageing and such acids do not interfere with smooth operations. There are other influences at work to make an oil unsuitable for further use.

Oxidation Tests

Oxidation is the most important factor to bring about deterioration of an oil in use, and in a vehicle engine this process of combination with oxygen is very significant as part of the oil is burnt up with every stroke. Oxidation is the main contributing factor making sump oil useless after a certain mileage. It is generally accepted that after 6,000 miles at the latest the oil has to be changed, although, on the other hand, oil mileages of 60,000 miles have been reached without any damage. There is not the slightest doubt that to change oil after relatively low mileage is a true economy.

Unfortunately, it is impossible to go into the details of the changes within the oil, but on the other hand the producer, as well as the consumer, always looks for a means of testing an oil quickly for stability. Many appliances have been devised for this purpose but it has been shown to be impossible to reproduce the conditions within an engine in a laboratory apparatus.

Many pages have been written in books and scientific papers in order to show which property of a liquid it is that makes it into a lubricant. The word "oiliness" is still much in use, but in spite of all the work done not much light has been thrown on that subject. It is certain that when speed and load conditions are equal and where surfaces are separated by a fluid film (full fluid lubrication) friction depends only on the viscosity of the lubricant. In its turn viscosity depends not only on the temperature but also on the pressure in the liquid. This latter point has, in the opinion of the author, been neglected during recent years.

Why mineral oils and fatty oils are superior to other liquids as lubricants has not yet been clearly established. Sugar solution and other liquids, for instance, have the same viscosity range as lubricating oils but refuse to lubricate. On the other hand, new liquids, synthetic plastics or otherwise, have been developed and are superior to oils as lubricants, but again the causes are unknown.

On surfaces where half liquid friction or boundary conditions prevail, the situation is different again. For such conditions, pure mineral oils have not sufficient lubricating power and have to be mixed with fatty oils or, more recently, have been doped by special additives. A huge new industry of additives has sprung up during the last 15 years or so and machine parts can be lubricated and protected from wear to-day in a way that would have been thought impossible not long ago. For examples there are the hypoids and some worm gears where there is point contact and the rubbing surfaces tend to weld together if the right additive is not present.

After reading what has been said in the foregoing paragraphs, the reader will be driven to the conclusion that it is quite impossible for a consumer or a public laboratory, given even ample facilities, to determine the quality of a lubricant and that the claims of the suppliers must be accepted at their face value. It must be admitted that this is almost true if the problem has been set in a rather general way, for instance if a newly developed lubricant is to be tested, or if a new kind of lubricant has to be developed. For both purposes elaborate engine tests and road tests in various conditions have to be undertaken. For example, before new lubricants were adopted for London buses, road tests were made with 40 buses at a time for six months and eventually great improvements were made.[2]

If, on the other hand, the problem is on a narrower scale, for example if it

has to be established which of two oils is of higher quality, or whether one particular oil is worth a premium price, a solution is well possible. Since many laboratories refuse to accept orders of this kind it is perhaps instructive to give a few hints on how to proceed:—

In the first place, the temperature viscosity curve has to be determined for those temperature ranges in which the oil will be used. Big differences may well be found. For one oil the curve may be flat, that is, the viscosity index is high, while for another it will be low. The oil with the higher index will then receive one good mark. There are oils on the market with viscosity index round about a hundred whereas others are as low as 60 or lower.

Despite the earlier criticism of specific gravity, this property can give an indication of the source of supply. Likewise, the behaviour at low temperatures can be instructive in this connection.

It is our practice in such a case to carry out an oxidation test, and again we seem to contradict ourselves. The answer is that it does not matter what kind of oxidation test is being made in a particular case provided that a standardized test is made with every oil in exactly the same condition. It has been possible for us to compile a valuable archive of test results, and in particular of oils that have been proved successful in long years of practical operation. When we compare the results for an unknown oil with these data it is less difficult to give an evaluation. Our oxidation test, or stability test, consists in keeping the oil at 225 deg F for 50 hours in a rather simple appliance with standardized oxidizing conditions. After 50 hours, changes in the properties of the oil are noted, and the figures compared with those of the new oil. In a limited way, it is also possible to test for additives. The oils are ignited and the ash analysed. It has been shown that rather a limited series of additives is in general use and we are in the possession of some data about it.

In these investigations allowance must be made for the fact that, apart from the few who buy very large quantities, most clients give careful consideration to the expense of the tests. Otherwise it could easily be the case that the tests cost more than the oil for a year. If, however, somewhat more can be spent, additional tests can be made in an engine without increasing the costs unduly. As mentioned before, great experience of oil technology is necessary before it is possible to form a reasonably accurate determination of quality by inspecting the oil in the sump and the inner parts of the engine after some 2,000 miles use. Only very rarely will there be the means to make a long engine or road test with wear measurements, etc. However, in general it will be possible to give a definite answer to the questions asked concerning the quality of a particular lubricant.

References

1 "The Significance of Tests of Petroleum Products"; published by the American Society for Testing Materials, Philadelphia, 3, Pennsylvania.

2 H. TENNANT; "This Oil Makes for Economy," *Bus and Coach*, May 1953.

BRAKE USAGE UNDER SERVICE CONDITIONS

To permit fairly rapid assessment of the performance of automobile brake-lining materials, testing machines are employed and, for the test schedules, detailed information is needed about the use made of the brakes under service conditions. Brake-lining performance depends mainly on the rate at which work is done and on the drum-surface temperature, the latter being largely governed by total work done, rate of working, and cooling effects. Information required in preparing test schedules is obtainable from records on a time base of speed, deceleration and rate of working, together with some indication of temperatures. In an investigation by N. Carpenter and R. Milne reported in *Research*, April 1954, apparatus furnishing such records in a vehicle in service is described.

A tachometer generator driven by the propeller shaft generates a voltage proportional to the angular velocity of the rear wheels. This signal is applied to one pen-coil of a high-speed, multi-pen recorder and is differentiated electrically, amplified and applied to a second pen-coil to give a record of deceleration. A voltage proportional to the rate of working, derived from the product of the hydraulic pressure in the brake system and the speed signal, is applied to the third pen; braking torque is assumed to be proportional to the brake-line pressure. Calibration of the unit for measuring rate of working was achieved through comparing the deflection of the pen with the rate of working as calculated from speed and deceleration records during constant deceleration stops on a flat road where only kinetic energy was dissipated. An indication of drum temperature is given by a thermistor soldered to the inner surface of the drum and connected to the remainder of the temperature unit through slip rings. Its output is amplified and applied to the fourth pen of the recorder.

Figures show: (1) results derived from a single brake application; (2) a diagram of the rate of working on a particular route together with the vertical section of the route. Types of brake application employed in service and their different effects on lining wear are described. High rates of wear are associated with intermittent braking on a downwards gradient with somewhat high speeds between applications. Particulars of braking time, cooling time and work done per brake application are tabulated for one car over many miles of road use. *M.I.R.A. Abstract No.* 6817.

CORROSION-RESISTANT COATING

A NEW coating for mild steel, comprising a nickel oxide, dibasic ammonium phosphate and water mixture which is applied to the surface by brush, dip, or spray, is described by G. J. Harvey in *Iron Age*, April 15, 1954. The coated parts are fired in standard furnaces, reducing the nickel oxide to form an alloy of nickel and phosphorus at a temperature (1600-2000 deg F) considerably below the melting point of either the base metal or nickel. A ternary alloy is also produced which forms a strong bond with the base metal. Ratios of nickel oxide to ammonium phosphate may vary from 2:1 to 20:1 and higher ratios of the phosphate lower the temperature needed to reduce, fuse and alloy bond the coating to the base metal. Pure hydrogen is the most successful reducing atmosphere. Carbon in the atmosphere or as a surface contaminant must be avoided, and degreasing before coating is necessary. Temperature of the eutectic point of the alloy of nickel and phosphorus (with 10 per cent phosphorus, 1600 deg F) has little adverse effect on most ferrous metals. Firing time is only that needed to obtain the required temperature at the skin; heavy coatings can thus be applied quickly and cheaply. The ternary alloy formed at the interface of the base metal and coating imparts to the coating the ductility of the base, and coated specimens may be bent through 180 deg without peeling or flaking. Coating hardness ranges from 38 to 42 Rockwell C.

Specimens relatively thinly coated have resisted salt-spray corrosion for up to 100 hr, and others have retained their finish after 10 years under normal atmospheric conditions. Performance of the coating depends largely on its continuity. Porosity varies with the ratio of phosphorus carrier to nickel oxide, and a mixture giving satisfactory coverage and minimum porosity is necessary. The unfired mixture may also be dried at 180 deg F to prevent formation of gas pockets during firing. *M.I.R.A. Abstract No.* 6814.

NEW PLANT AND TOOLS

Recent Developments in Production Equipment

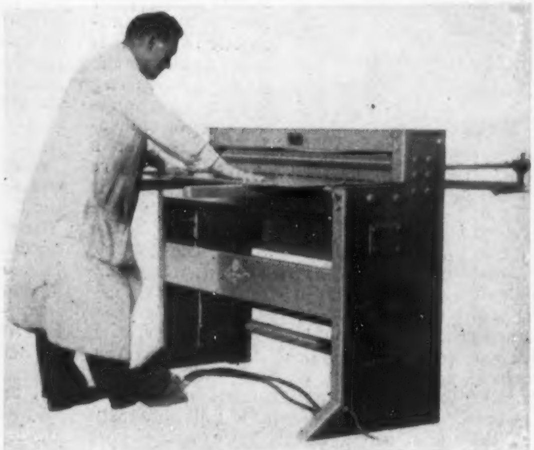


Fig. 1. Besco air-operated guillotine
F. J. Edwards Ltd.

TO the wide range of Besco metal working machines, F. J. Edwards Limited, 359-361, Euston Road, London, N.W.1, have recently added two guillotines operated by pneumatic pressure. They differ only in width, the model AIR 316, which is illustrated in Fig. 1, being 36 in wide and the model AIR 416 49 in wide. Each machine will shear mild steel sheet up to 16 s.w.g. thickness, and other materials in proportion. The standard shearing blades are 36¾ in and 49 in long respectively. All kinds of sheet metal, including brass, copper, aluminium, duralumin, tinplate and zinc can be cut. With the standard blades ground to a special angle, softer materials such as rubber, mica, plastics, fibre, veneers, gauze and card can also be cut. Special blades, hardened and ground, suitable for cutting stainless steel can be supplied at extra cost. Adjustable back and side gauges, which gauge up to 20 in from the back stop and 24 in from the front, are fitted. A special graduated side gauge can be supplied as an extra.

The machine is designed to work from air line supply at a working pressure of 80 lb/in^2. Power is supplied through two Marton air cylinders, which have their rams connected by link motion to the movable top shearing beam. The shearing beam is returned automatically to the top of the stroke by air pressure. Either individual or repeat action can be employed. The cutting beam guides are of gun metal and are adjustable, while the top of the cutting beam is covered in sheet metal to give the operator full protection. Whilst they are being cut, the sheets are gripped and held steady by an automatic hold-down, which also acts as an adequate guard for the shear blades.

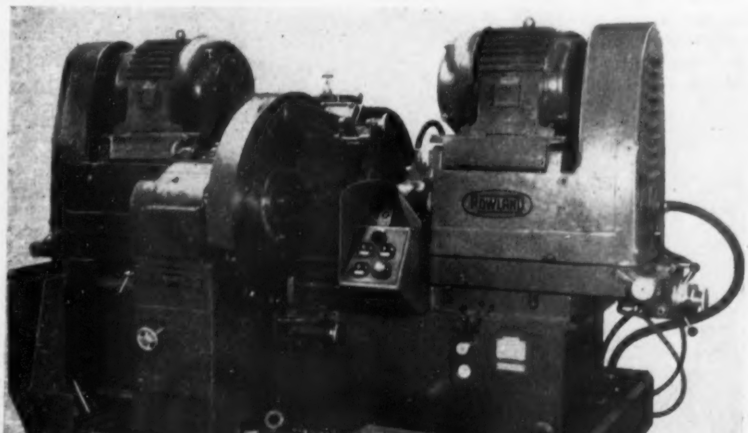


Fig. 2. Rotary duplex surface grinder
E. Rowland and Co.

Rotary duplex surface grinder

A machine recently developed by F. E. Rowland and Co. Ltd., Climax Works, Reddish, near Stockport, for simultaneously grinding two opposite surfaces on permanent magnets is illustrated in Fig. 2. This rotary duplex surface grinder incorporates certain special features to allow accurate work to be produced at high output rates. It allows the operation to be carried out at a production rate up to 15 times greater than is possible by normal single side surface grinding.

The machine bed is of substantial fabricated steel construction, provided with cast iron shears upon which the grinding wheelheads slide. The grinding wheel slides carry a large diameter high tensile steel spindle mounted on precision preloaded bearings, and provision is made to ensure that any temperature rise in the spindle will not affect the accuracy of the work.

Each grinding wheel spindle carries a 30 in diameter abrasive disc of a specification to suit the work to be ground. Both wheelheads are universally adjustable. This allows the grinding wheels to be set relative to each other and to the work carrier, since these settings vary according to the type of work to be ground and to the degree of accuracy required. The work carrier consists of a circular steel disc fitted with hardened master bushes, into which work bushes are inserted to carry the magnets. This arrangement permits work of various sizes and shapes to be accommodated in one work carrier, and thus minimizes the changeover time from one type of magnet to another.

Drive to the work carrier is by means of a standard foot-mounted motor through vee belts and worm reduction gear. A friction clutch is incorporated in this drive to ensure damage does not occur if oversize workpieces are fed into the machine. The components are loaded by hand into the work carrier. A simple ejection device is used to unload them after they have passed the grinding area.

The wheelheads are held up against dead stops by means of hydraulic power. To prevent any possibility of coolant entering and contaminating the hydraulic system, the hydraulic pump, reservoir and ancillary equipment are located outside the machine bed. To enable rapid adjustment to be made to the position of the grinding wheelheads to compensate for wheel wear, an electro - hydraulic device is fitted to each wheelhead. It allows pre-set variable increments of feed to be applied,

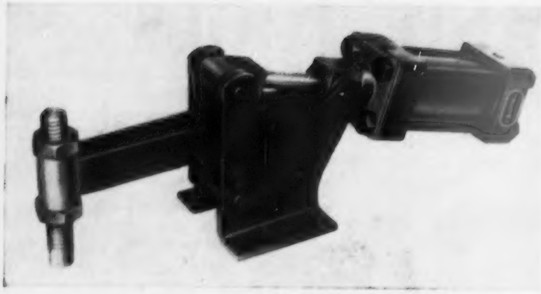


Fig. 3. Speetog air-clamping unit
Speed Tools Ltd.

without interruption of the feeding operation, by pressing a push button at the operating position. A substantial wheel dressing device is provided. It is hydraulically operated, and will accommodate either cutters or diamond tools. The machine is arranged for wet operation, and is designed for operation by unskilled labour. A warning light is incorporated and is illuminated when the grinding wheels need replacing. On this machine opposite sides of permanent magnets are ground simultaneously at rates up to 40 per minute, depending upon size. On quantity production accuracy can be maintained within 0·001 in for size and to 0·0001-0·0002 in for parallelism.

Speetog air clamp

A self-contained air clamping unit developed by Speed Tools Limited, Vereker House, London, W.1, is illustrated in Fig. 3. The specially designed "Airtog" cylinder is of the double acting type and has automatic cushioning on both the forward and reverse strokes. A small pocket of air is trapped in a chamber at each end of the stroke, thus ensuring high speed operation without any hammering effect on the component that is being clamped. By means of two small screws in the end of the cylinder cover, the degree of cushioning is readily adjustable. The piston is fitted with self-sealing rings, and the piston rod gland is also of the self-sealing type.

Two advantages are claimed for this air clamp. First, the toggle action principle with its "lock over centre" ensures that the clamp stays fully locked in the event of failure in the pneumatic system. Secondly, the toggle action increases the pressure exerted by the cylinder by more than 20 times. Therefore, this clamp provides a safe method of securing the work, and in addition gives much greater pressure than is normally obtained from an air cylinder. It allows for high speed operation with secure and closely controlled clamping pressure. Any number of these clamps can be operated instantly at the touch of a switch, or they can be arranged to operate in any desired sequence.

High-speed gear hobber

There is not the slightest doubt that the "Hydrax" gear hobbing machine, illustrated in Fig. 4, and produced by The David Brown Machine Tool Division, Britannia Works, Sherborne Street, Manchester 3, will arouse great interest in the automobile industry. It is a single-spindle gear hobbing machine with a production rate equivalent to that of a multi-spindle machine, and is designed for the rapid generation of spur and helical gears by either climb or conventional hobbing. The maximum hob speeds possible with this machine are considerably in excess of normal requirements for single and multi-start high speed steel hobs. They are, in fact, high enough to allow full use to be made of tungsten carbide tools.

The cutting cycle is fully automatic and is controlled by a single push button. A quick clamping arrangement fitted in the work spindle allows work to be loaded and unloaded quickly and effectively. The hydraulic feeds are steplessly variable up to $\frac{1}{8}$ in per revolution of the work. They allow gears to be produced consistently well within the limits of accuracy required for subsequent shaving operations. Lead cams or differentials are not required for spiralling, and the use of simple hob and table drives, involving a minimum number of gears, obviates the multiplication of small errors.

Because of the rigid construction of the machine, there is freedom from vibration at all speeds of operation. Furthermore, to ensure that the position of the hob relative to the work is positively maintained during cutting, the column is rigidly clamped by hydraulic pressure, with four bolts to the bed and two to the over-arm support. In effect, the column is locked solid with the main frame. Despite its massive construction the machine occupies only 78 in × 84 in floor space. It is also easy to operate, and to load, and as the hob slide is always nearly horizontal, hob removal is a simple matter.

The principle of the Hydrax is that the work axis is inclined to the direction of the hob feed at the helix angle of the gear to be cut, while the hob slide is set angularly to the worm angle of the hob. When cutting, the hob is traversed in a vertical direction along the helix and very considerable reductions in hob traverse are made in comparison with conventional methods. For absolute minimum hob traverse, the hob is plunge fed to depth. A feature of the machine is that in cutting helical gears, the point of first contact on the hob is some distance from the point where contact ceases, giving what is termed "relative" hob shift. This is automatic and is due to the contact moving along the hob as it feeds through the work. The amount of "relative" hob shift is dependent upon the helix angle and face width of the gear blanks. A hand-operated hob shifting arrangement is incorporated so that hob wear can be uniformly distributed when spur gears or helicals with small helix angle are being cut.

Hobs up to 7 in diameter and 7 in width can be accommodated on the rigid, precision built hob slide. The hob spindle is carried on taper roller bearings and runs at speeds up to 600 r.p.m. Worm gears are used for the final drive to the spindle, and the wheel of this drive is in halves so that angular adjustment can be made to eliminate undue backlash. As the same change gears are used for both hob speeds and indexing, a great range of hob speeds is available. Since the work axis is inclined to the helix angle, it is only necessary to swivel the hob slide to the required worm angle of the hob. The degree of swivel is a minimum

Fig. 4. Hydrax high-speed gear hobber
David Brown Machine Tool Division

and takes place either above or below the horizontal position according to the hand of the hob. Angular readings are indicated on a vernier scale, and the whole assembly is designed to facilitate precise setting of the hob slide.

The work spindle is carried on taper roller bearings. To minimize pitch errors in the work, the dividing worm wheel is larger in diameter than the maximum blank for which the machine is designed, and to eliminate backlash in the final drive worm gears, the worm wheel is in halves, at right angles to its axis, to allow angular adjustment of one half in relation to the other. The work is clamped by a strong helical spring capable of exerting a maximum clamping force of 15 tons. This spring is housed in the spindle and is compressed by hydraulic pressure to release the work.

An extremely efficient hydraulic system controls the movements of the column, hob slide, rotating centre and work rlease. It comprises three sections:—(a) pump unit powered by 2½ h.p. motor; (b) a panel, housing control valves for column in-feed, column clamping and hob slide traverse; and (c) workhead section containing valves for controlling traverse of rotating centre and the quick release mechanism for unclamping the work. The valve for the quick release mechanism is hand-operated and is electrically interlocked with the automatic cycle to prevent the machine from operating with the work unclamped.

When the work is locked in position on the spindle, operation of the "start" button initiates the following automatic cycle:—

(1) Main and coolant motors start whilst the revolving centre feeds into the work arbor under hydraulic pressure, which is uniformly maintained throughout the cutting cycle.
(2) The column plunge feeds the hob to depth.
(3) The column is clamped in the cutting position.
(4) The hob feeds through the work in a vertical direction.
(5) The column is unclamped.
(6) Quick traverse of the column away from the work.
(7) Main and coolant motors stop and the centre withdraws from the work arbor.
(8) Quick traverse of the hob slide to the start position.

The various machine motions can be controlled independently by hand for setting. Adjustable stops control the column in-feed hob slide traverse. The final setting of the work spindle is effected manually through gearing that produces angular movement of the cradle equivalent to one minute of arc for each revolution of the dial. When any appreciable change of angle is required, a power drive can be brought into operation. Should the main motor become overloaded during the working cycle, the feed stops immediately and the hob returns to the start position. An emergency stop button is provided. This, when pressed, instantaneously stops all machine movement.

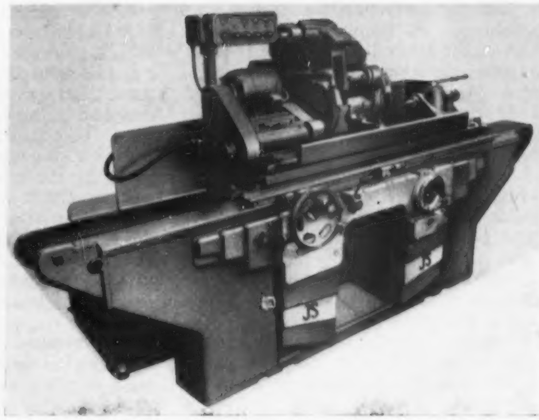


Fig. 6. Semi-universal grinding machine
A. A. Jones and Shipman Ltd.

Grinding machines

Three recent additions to the range of grinding machines designed and built by A. A. Jones and Shipman Ltd., Narborough Road South, Leicester, are illustrated in Figs. 5, 6, and 7. A precision spindle and internal grinder is shown in Fig. 5. Although this machine is suitable for producing work to extreme toolroom accuracy, it is primarily designed for production grinding and incorporates special features to ensure that close limits of accuracy are maintained on repetition work.

The table traverse is hydraulically variable over a wide range, and a special feature of the hydraulic control gear is that, regardless of changes in traverse speed, the reversing point of the table can be maintained to very close limits. This makes it practical to grind to shoulders without undercuts. In addition, this feature, together with the fact that a short stroke of 0·020 in can be obtained, is important in plunge grinding, since it affords the possibility of grinding up to or between shoulders without excessive clearance. The ultra-short stroke can be operated at full throttle opening and the table reverse is shockless at all speeds. A sensitive hand movement to the table is engaged automatically when the power traverse is disengaged, and is automatically uncoupled immediately hydraulic motion is in operation. The table is arranged to swivel in both directions for taper grinding.

Particular attention may be drawn to the wheel-head cross-feed, which has intermittent and a coarse and fine continuous feed in addition to a quick

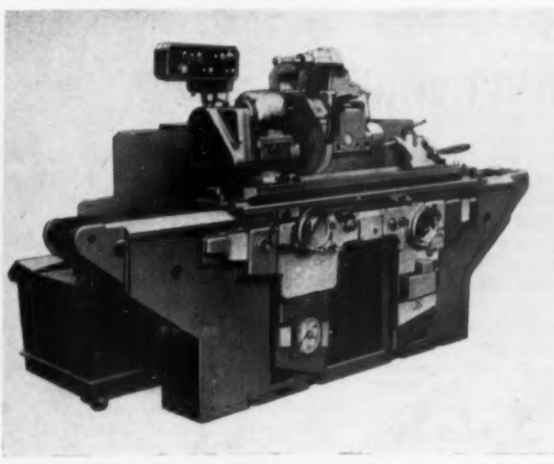


Fig. 5. Precision spindle and internal grinder
A. A. Jones and Shipman Ltd.

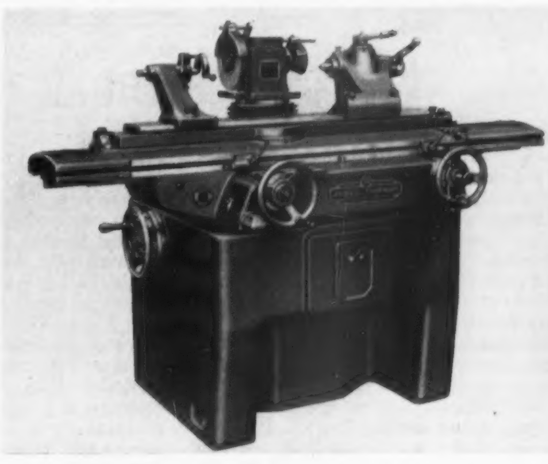


Fig. 7. Tool and cutter grinder
A. A. Jones and Shipman Ltd.

in-feed and retraction for loading and unloading. A timing device is incorporated for control of "spark out" prior to automatic stop. The cross-feed handwheel is graduated in easily read divisions, each equivalent to 0·0002 in off diameter. There is also a secondary dial graduated to give direct readings of the actual reduction in diameter, while a fine feed handwheel, arranged inside the main handwheel, provides a feed ratio one-tenth that of the main feed.

For automatic stop operation the component is placed between centres and a latch knob is depressed by the operator. The main control lever is then moved to the "in" position, where it will remain on release of the latch knob; this ensures that both the operator's hands are clear of the work when starting the machine cycle. The workhead, table oscillation (if in use) and coolant supply then start, and the wheelhead moves in and feed starts at a coarse rate set by the "coarse" throttle. At a predetermined point, set by a dog, the feed rate is diminished and grinding continues at the low rate until the feed is stopped by a dead stop. A timing arrangement, which can be set to give a dwell of from two to 20 seconds, is brought automatically into operation at dead stop. At the conclusion of the pre-set dwell, the wheelhead retracts and resets and all other motions cease.

The internal grinding unit is of the drop-down arm type. It is arranged to fit on top of the external grinding wheelhead. A motor provided with the attachment drives the internal grinding spindle through an enclosed endless flat belt. An electrical interlock ensures that the internal spindle will not run until the external wheel is stationary and vice versa. The driving belt need not be removed or refitted when a change is made from one type of grinding to the other, since it is arranged to be applied and tensioned automatically when the internal head is brought down to the grinding position.

A fairly conventional type of tailstock with a lever-operated centre is the standard fitment for this machine, but a special tailstock with ball-slide movement and provision for full range diamond truing can be supplied at extra cost. This tailstock has been designed to allow the grinding wheel to be trued in the correct generating plane without disturbance of the work, retraction of the wheelhead or re-setting the table stops. These machines are available in two sizes, each having 10 in maximum diameter swing, but the maximum grinding lengths are 27 in and 40 in respectively.

A semi-universal precision grinding machine is shown in Fig. 6. As regards table control, cross feed and internal grinding, this machine embodies the same design features as the Jones and Shipman machine described in the preceding paragraphs. The special feature is the double swivel wheelhead. This unit is mounted upon a slide that has an adjustment of 5 in to cover the extreme range of work required from the machine. The wheelhead unit and slide are mounted on a compound slide that can be swivelled to 90 deg on either side of its normal position to facilitate the grinding of acute tapers, both external and internal. This assembly is then mounted on the main feeder slide, and the whole assembly is finally mounted on a swivelling base, which can also be swivelled from its normal position, 90 deg clockwise and 75 deg anti-clockwise.

The wheel spindle is so arranged that a wheel may be mounted at either or both ends, as may be desirable. This arrangement eliminates the need for a change-over of belt drive. Furthermore, the wheel, when mounted on the right-hand end of the spindle adjacent to the belt drive, does not overhang further from the wheel spindle bearings than does the wheel at the left-hand end of the spindle, which is the normal position for straightforward grinding operations.

Fig. 7 shows the latest Jones and Shipman tool and cutter grinder. The table of this machine is mounted on a central spigot and bush and is arranged to swivel on its slide. A locking clamp is arranged at each end, and the table can be swivelled 8 deg on either side of zero for long taper work. For more acute tapers, the table can be swivelled up to 90 deg in the left-hand direction and 45 deg to the right, with double locking on a central facing. The stop dogs on the table may be set to limit the stroke, either as positive dead stops for grinding close to a shoulder or as shock absorbing stops with spring-loaded ends.

The cross slide carrying the table is mounted on wide spread slides, one a vee and the other a roller chain slide. To ensure accurate movement, the cross screw is located immediately above the vee slide. Control of the cross feed movement is by handwheels at the front and rear of the machine. Both handwheels have adjustable graduated dials, which can be set to zero at any position so that the operator does not need to calculate the final reading.

Particular attention has been paid to the design of the wheelhead. The flanges for the larger diameter grinding wheel are fitted with balance weights, so that by means of the balancing mandrel provided, the wheel can be accurately balanced. Provision is made for swivelling the wheelhead pillar to any desired angle; a graduated ring facilitates accurate setting. Elevation is effected by means of two graduated handwheels, each fitted with an adjustable dial graduated in increments of 0·001 in.

The universal cutter head is adjustable in centre height to allow between 8 in and 12 in swing. It can be swivelled in both the horizontal and vertical planes and can be securely locked. The spindle is arranged to take indexing mechanism (supplied as extra equipment) for accurate spacing. Special attachments that greatly increase the scope of the machine are available as extra equipment.

MOBILE CONVEYORS

A NEW range of mobile conveyors, manufactured by Fourways (Engineers) Ltd., of Thornwood Common, Epping, has recently been developed. The types available are Models D, P, and E.25 Electricar Mobile Conveyors. All consist essentially of a four-wheeled electric vehicle on which a conveyor is mounted. In the demonstration, the units were used as elevators to load luggage into an aircraft, but they have many other applications, such as handling stores and loading vehicles.

In Model D, the endless conveyor track is on two booms pivoted together on the vehicle. The booms are mounted in line in a fore and aft position relative to the vehicle, and the front and rear ends of the track assembly can be elevated or depressed by an electro-hydraulic mechanism to suit the loading and unloading heights required. At the rear, the minimum height is 1 ft 3 in and the maximum 5 ft. The front end can be raised to 14 ft 6 in or lowered to 5 ft. The conveyor is designed for unit loads of 2-cwt and a maximum load of 6 cwt.

Model E.25 is similar in many respects, but the driver's seat is not enclosed by a cab. The rear boom can be raised to a maximum of 6 ft and the minimum height of the end of the front boom is also 6 ft.

The Model P is a much smaller unit and has only one boom, the rear end of which is pivot mounted on the chassis. A pedestrian-controlled chassis is employed. The loading height is 2 ft and the delivery height ranges from 6 ft to 11 ft. It is designed for a unit load of 2 cwt and a maximum load of 4-cwt, and its delivery rate is 50 ft/min.

All the conveyors are mounted on Morrison, battery-operated electric chassis built by Austin Crompton Parkinson Electric Vehicles Ltd. The battery capacity and make can be varied according to customers' requirements. Charging can be effected at off-peak periods. It is claimed that the amount of electricity consumed by the larger chassis is 0·9 units per mile.

THE BEIER GEAR

An Infinitely Variable Gear for a Wide Range of Applications, including Automatic Transmissions

THE development of an infinitely variable gear for the transmission of horsepowers of useful magnitude has been the aim of engineers throughout the ages, but mechanisms of this type have not yet been adopted for transmission systems of any quantity-produced motor vehicles. However, a gear system that is said to fulfil the requirements for the transmission of powers from 1-2,000 b.h.p. or more has been developed by Dr. Joseph Beier of the Beier Infinitely Variable Gear Co. Ltd., 19, Ebury Street, London, S.W.1. An automobile automatic transmission based on this system has also been developed. The curves in Fig. 1 show that the mechanical efficiency of this transmission varies from about 62 per cent when the output shaft speed is 20 per cent of engine speed, to about 97½ per cent when the input and output shaft speeds are identical. In the particular system for which these curves were obtained, direct drive is engaged when the output shaft speed rises to 80 per cent of that of the input shaft. At this point the efficiency is about 95 per cent. A range of speed ratios from 1:1 to 4:1 or 6:1 is normally provided, but an even greater range can be obtained if necessary. The system is said to be silent, reliable, smooth running and to need little maintenance.

Before Dr. Joseph Beier turned all his attention to the development of infinitely variable gears, he was for many years with Brown Boveri and Co., of Mannheim, where latterly he was chief designer. He has developed infinitely variable gear systems for one of the cars designed by Dr. Porsche

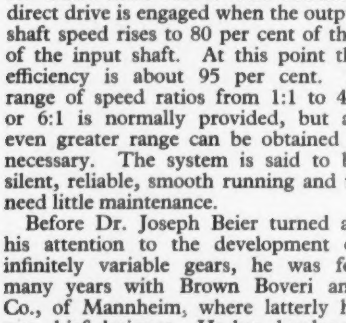


Fig. 1. Performance curves of the GA type transmission

and for a 5 ton truck powered by a 150 b.h.p. diesel engine. The car is said to have been run successfully for more than 15,000 miles and the truck for more than 5,000 miles. The development work was interrupted by the war, but subsequently further improvements have been made and the latest completely automatic, infinitely variable gear for trucks and buses is now being constructed in England. The system has also been applied to constant speed drives for aero engine superchargers and engine driven generators. Generator drives have been successfully tested at speeds as high as 6,000 r.p.m. The higher the speed the greater the power that can be transmitted by a gear of a given size.

General principles

A noteworthy feature of the arrangement is that the power is transmitted by the drag force in thin films of oil, temporarily of very high viscosity, between the driving and driven wheels. Therefore, metallic contact does not take place between the wheels. The driving and driven members each consist of an assembly comprising a number of discs on a common shaft. The discs on one shaft are of conical section, that is, tapered from the centre to the periphery. Those on the other shaft are flat discs flanged at their peripheries, and the faces of the flanges are chamfered to seat on the faces of the conical discs between which they are interposed, Fig. 2. All the discs are splined on their shafts on which they are free to float axially, except in so far as they are constrained by a compression spring that bears against an end plate that holds the assembly together in a manner similar to that employed in some friction clutch units. The transmission ratios are changed by varying the distance between the axes of the driving and driven wheels.

The number of discs adopted in the design depends upon the power to be transmitted. To increase the capacity of the gear, a larger number of discs can be employed. Alternatively larger diameter discs can be used; a face cam or other device can be incorporated to increase the axial pressure exerted by the spring; or a number of sets of flanged discs, spaced equally round the periphery of a single set of tapered discs, can be employed. In units incorporating a number of sets of flanged discs, each set is mounted on a separate pivoted arm, and the motions of all the arms are synchronized so that the axes of the flanged discs are always equidistant from the axis of the tapered discs.

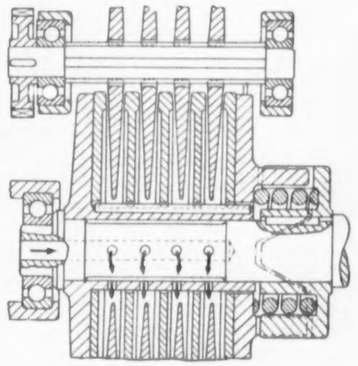


Fig. 2. This diagram illustrates the principle of the friction drive arrangement of the Beier gear. Note the oil flow path indicated by arrows

The film of oil between the discs is constantly renewed by their rotation. In the area of contact it is temporarily subjected to a high pressure, which considerably increases its viscosity. This high viscosity makes possible the transmission of the power by the oil film. The drag force that can be reacted depends on the area of contact and the thinness of the oil film. Mathematical analysis shows that the area of contact in the Beier gear system is much larger in proportion to the size of the components than can be obtained with any other arrangement. Furthermore thin discs of this type have the advantage of being compact and light so inertia effects are correspondingly small.

Under normal conditions, the gear has the capacity to transmit its rated power with negligible slip. Therefore its efficiency is high. However, if the gear is overloaded, appreciable slip occurs. This increases the drag of the oil films and therefore the load carrying capacity of the gears. Thus, the system can be run at loads considerably above its rated value. In these circumstances, the efficiency is lower and the assembly becomes hot. Nevertheless, there is no possibility of metal-to-metal contact between the discs, so that wear is negligible.

Lubrication can be effected with oils of a light grade and of the usual properties. It is, however, desirable that the viscosity of the oil, so far as possible, should be maintained constant regardless of changes in temperature. In the smaller units, the heat generated is carried away by the oil and radiated through the casing, which may be finned, but a separate oil cooler may

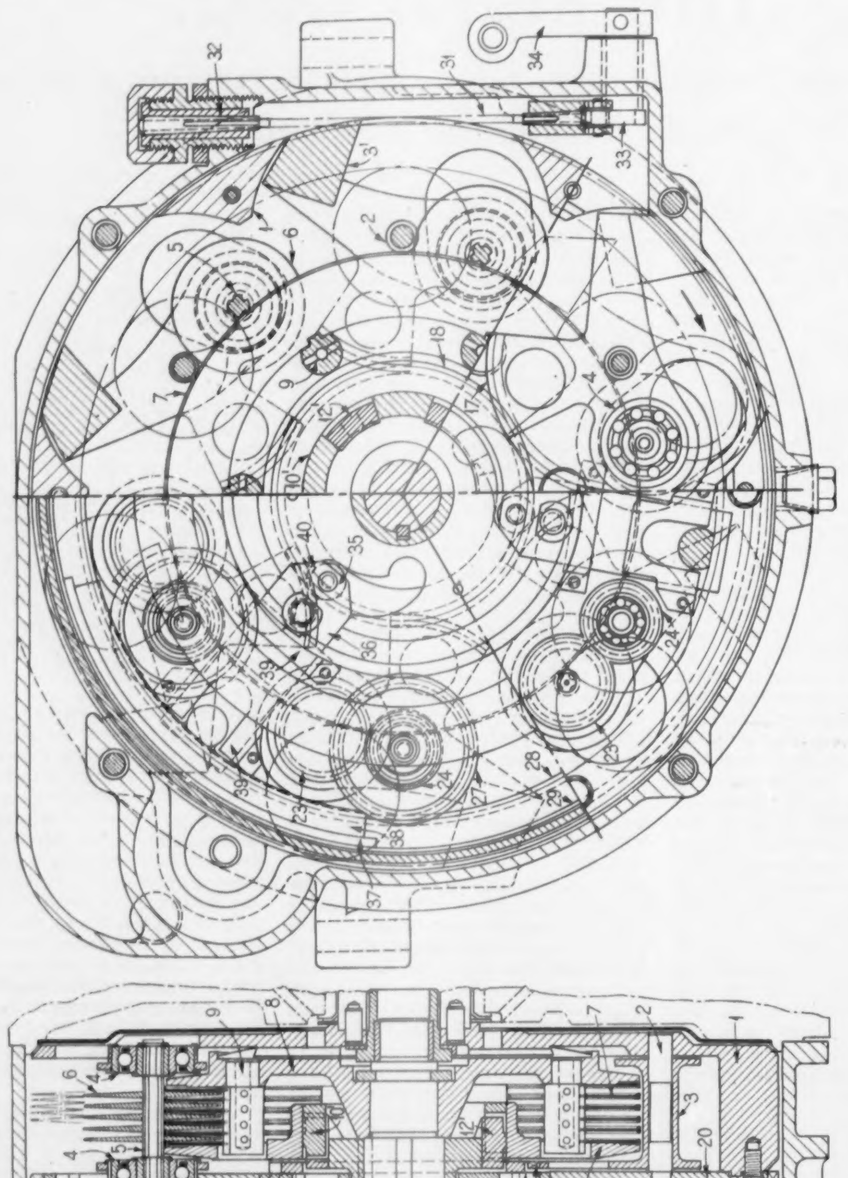


Fig. 3. GENERAL ARRANGEMENT OF THE BEIER GEAR FOR AUTOMOBILE AUTOMATIC TRANSMISSIONS
Six swinging arms are employed in this unit to carry the tapered discs

be needed in the larger sizes used for automobile applications. Silent running is obtained because the action of the discs as they roll over one another is smooth and constantly cushioned by the oil film. The only source of noise in the unit is the meshing of the teeth of the coupling gears and of the idler wheels. If these are manufactured reasonably accurately, the transmission unit runs as silently as an electric motor.

Automatic transmissions

The advantages claimed for the Beier automatic transmission for cars are as follows:

1. The infinitely variable gear ratio is automatically adjusted to suit engine speed and output torque, resulting in:
   a. Fuel economy
   b. Less wear on the engine, tyres and brake linings
   c. Easier driving
   d. Greater safety resulting from simplified controls
   e. Improved performance, since maximum engine power can be used at any road speed. Alternatively a smaller engine can be used to give the same performance with reduced first cost, lower fuel consumption and less weight.
2. Simplified controls. The car is controlled by the accelerator and brake pedal only.
3. Free-wheel action, reducing fuel consumption and general wear. The free-wheel is locked up simply by a partial application of the brake pedal.
4. The car cannot roll backwards on hills.
5. A separate reverse gear is not required.
6. Direct drive is obtained at cruising speeds, so that there is no wear on the transmission during the greater part of the time. The driver can change to the indirect ratios whenever he wishes.
7. High mechanical efficiency.
8. The following important manufacturing advantages:
   a. The transmission can be accommodated entirely within the flywheel, and the space normally occupied by the gearbox is saved. This is a particularly useful feature for front wheel drives or rear engined cars
   b. The mass of the flywheel is usefully employed. In other words, the weight of a conventional gearbox is saved
   c. All parts of the transmission are suitable for quantity production
   d. Great flexibility of design. The capacity of the transmission can be made greater either by employing more discs on each swinging arm, or by increasing the number of swinging arms.

In this version of the Beier gear, the flanged discs are mounted on the output shaft of the transmission, and the tapered disc assemblies rotate about them in a planetary manner. The rotational speed of the output shaft varies according to the depth of engagement of the discs, which is automatically adjusted to suit engine speed and output torque. When the rotational speed of the output shaft approaches 15-20 per cent of the engine speed, direct drive is automatically engaged and the whole mechanism rotates as a solid unit. This means that, in passenger cars, there is unlikely to be any wear on the system for 80-90 per cent of the driving time. The transmission can give an infinitely low ratio and even go beyond to a negative ratio, so a separate reverse gear is not required.

A general arrangement drawing of a unit designed for a rear engined car is shown in Fig. 3. For an engine developing 25 b.h.p. at 3,000 r.p.m., the diameter of the transmission of this type is about 12 in. Another transmission assembly has been designed to fit into a flywheel housing, about 22 in. diameter by 9 in axial length, for a bus engine developing 140 b.h.p. at 2,000 r.p.m., Fig. 4. The assembly illustrated in Fig. 5 is another variant of the transmission, with the cover removed.

Constructional details

From Fig. 3, it can be seen that each set of tapered discs (6) is mounted on a splined shaft (5), which runs in ball bearings (4). Each splined shaft is carried at one end of a swinging arm (3). The swinging arms are pivoted on the pins (2), which are mounted in the flywheel (1). At the other end of each swinging arm there is a counterweight (3′), which not only balances the centrifugal force due to the mass of the set of tapered discs, but is of large enough mass to force the tapered discs inwards toward the axis of the transmission with a force that increases as the engine speed rises. The tapered discs (6) intermesh with flanged discs (7) which are concentric with the axis of the transmission and are carried on the key-pins (9) fixed in the end disc (8). These key-pins also register in the other end disc (10). The end discs are free to rotate relative to the output shaft (12), except in so far as they are constrained by a face cam (10′) secured to the disc (10). This cam engages with a counter cam (12′) fixed to the output shaft. The end discs, driven by the pins (9), rotate with the flanged discs, and the torque is transmitted to the output shaft through the face cams.

The axial thrust of these face cams presses the flanged discs together in proportion to the torque applied to the output shaft. This pressure, acting against the influence of the centrifugal force on the counterweights, tends to squeeze the tapered discs out of mesh. The face cams function in both directions of rotation and are therefore effective when reversing or when the car is overrunning the engine, as well as during normal running.

On the swinging arms (3) there are also toothed segments (17) which mesh with a common gear ring (18). In this way the motion of all the swinging arms is synchronized. In Fig. 6 are shown the segment (17) and one of the swinging arms, and the tapered discs on their splined shaft. Steel rings (19) and (20) support the pivot pins (2). The inner periphery of the ring (20) forms a bearing for the carrier (22) to which is secured the ring gear (18).

On the ends of the splined shafts (5) are mounted the inter-meshing gear wheels (23) and (24). The wheels (24)

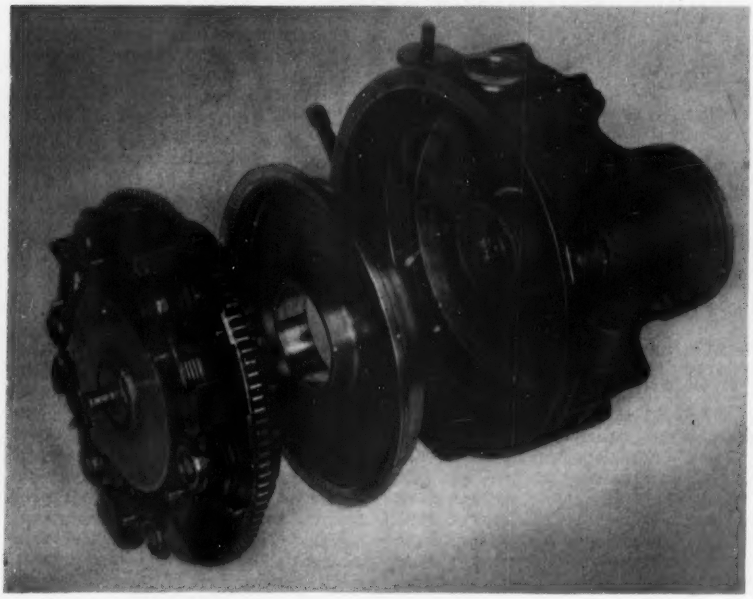


Fig. 4. The main components of a Beier automobile type gear, showing how they fit into a flywheel casing

run on ball bearings on the pivot pins (2). On the pivot pins are mounted the gears (27), which mesh with an internal ring gear (28). This ring gear is fixed to a carrier (29). The carrier is free to rotate on a plain bearing (30) and round its periphery is a wire-coil type free-wheel (31). One end of this coil is fixed to the transmission housing by means of the adjustable anchorage (32), while the other end can be tightened by means of the crank (33) and is operated by the lever (34).

Rollers (35) work in scroll shaped slots in the ring gear carrier (22). Connected to these rollers by means of shackles (36), which are guided by yokes (39), are brake shoes (38) with brake linings (37). These brakes come into contact with the inside of the gear carrier (29) when the rollers drop into notches (40) at the ends of the scrolls. This can only happen at the position of the adjusting ring carrier (22) that corresponds to the innermost position of the tapered discs, that is, at the highest gear ratio of the transmission.

Starting from rest

When the car is stationary and the flywheel, and with it the pivot pins, are rotating at idling speed in the direction of the arrow, Fig. 3, the tapered discs are held in the outermost position by the pressure of the face cams (10′) and (12′). If necessary, this pressure can be augmented by a suitable compression spring, acting on the flanged discs. Since the car, and therefore the flanged discs, is at rest, the internal ring gear (28) also rotates freely in a clockwise direction (provided the free-wheel is released). As soon as the engine is accelerated by opening the throttle, the counterweights force the tapered discs inwards.

The reduction ratio of the transmission at any position is given by the equation :

$$Ue = 1 - \frac{X}{R} \times \frac{r_3}{r_1} \times \frac{r_2}{r'_2}$$

where X = Effective running diameter of the tapered discs
Ue = Speed ratio between engine and output shaft
R = Fixed diameter of the flanged discs
r_3 = Diameter of the ring gear (28)
r_1 = Diameter of the gear (23)
r_2 = Diameter of the gear (24)
r'_2 = Diameter of the gear (27).

At a certain value of X, which will be called $X = x_0$, the equation becomes $Ue = 1 - 1$, and beyond this point, the value of Ue changes its sign. As the engine speed becomes greater and the discs are moved inwards from their outermost position, the speed of the outer wheel becomes gradually less until the position $X = x_0$, when it tends to change its direction of rotation. The outer wheel is prevented from doing this by the wire coil of the free-wheel. Thus, the car begins to accelerate and its initial reduction ratio is $1 : \infty$. As the engine speed is further increased the tapered discs are gradually forced further into mesh with the flanged ones, and the reduction ratio automatically approaches closer to the value 1:1. When the ratio has approached to within 15-20 per cent of this value, the movement of the arms (3), transmitted through the toothed segments (17) to the adjusting ring (18) and its carrier (22), causes the notches (40) to engage the rollers (35). This allows the brakes (37) and (38), with the assistance of centrifugal force, to engage the carrier (29) of the outer wheel (28) which it accelerates from rest to engine speed. Then the whole transmission rotates as a solid unit. The greater the engine speed the greater the accelerating force.

Driving uphill

If the car with the transmission in direct drive, is driven up an increasingly steep gradient, the engine speed gradually decreases until either :

The increasing torque and the increasing pressure of the face cams (10′) and (12′) on the flanged discs forces the tapered discs outward and causes the toothed segments (17) to rotate the adjusting ring (18) and its carrier (22) with such force that the remaining centrifugal force of the brake shoes on the rollers (35) is overcome, or:

if previously, while the car has been running at a higher speed, the driver has locked the outer wheel by means of the lever (34), the transmission remains in direct drive until the lever is released.

The lever (34) can be arranged, for instance, so that it can be actuated by depressing the accelerator against a spring stop beyond the full throttle position. With this arrangement, hills can be taken in direct drive so long as the engine does not stall. When a change is made to indirect drive, the transmission ratio is adjusted automatically so that the engine speed remains practically constant for a given throttle position. It is impossible to stall the engine, even against very great resistance, because under such conditions the ratio automatically approaches $1 : \infty$. The maximum torque that can be developed is limited only by the design of the particular transmission.

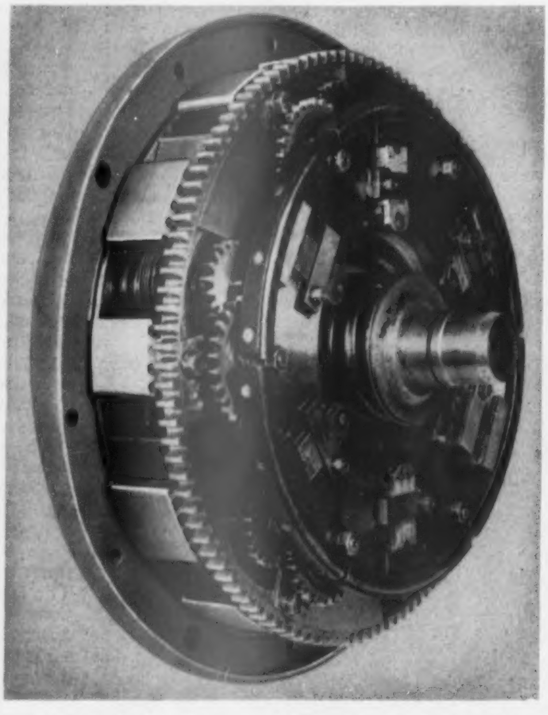


Fig. 5. The GA type transmission with its cover removed

Free-wheeling and using the engine as a brake

If the throttle is closed while the car is being driven on the indirect ratios with the car overrunning the engine, the outer wheel (28) is released by the free-wheel (31). This free-wheel action helps to reduce fuel consumption.

When braking on level roads, the brake pedal can be so arranged that during the first part of its travel it actuates the lever (34), which tightens the free-wheel coil (31), without actually applying the wheel brakes. In this way, a variable braking force can be applied to the outer wheel of the unit. In these circumstances, the car will drive the engine in a gear ratio that will increase in proportion to the torque reaction to the output shaft of the transmission. As the car slows down the transmission adjusts itself to maintain practically constant engine speed. Therefore on occasions when the car has to be slowed slightly without actually applying the wheel brakes, the engine is kept running at speed, ready to take up the drive instantly.

When braking is necessary on a downward gradient, the wire coil free-wheel can be used to brake the outer wheel (28) to a greater or lesser extent by partially depressing the brake pedal as already described. The driver can thus use a higher or lower engine speed to give an infinitely variable braking force. With the outer wheel fully locked, the braking force is considerable.

Reversing

When the engine is idling, the outer wheel (28) rotates forwards as already

described. If this outer wheel is braked by a slight movement of the brake pedal, the vehicle begins to move backwards. The speed of the vehicle in reverse will not increase, however, if the engine speed is increased, because centrifugal force drives the tapered discs deeper into mesh with the flanged ones. At very high engine speeds, the car will come to a standstill as the condition $X = x_0$ is reached.

The speed of the car in reverse is greatest at the smallest throttle opening, and since the reverse ratio is very low, the vehicle will only travel backwards slowly. If the car is stopped when climbing a gradient, and begins to run back, the gear ring (28) is turned in the direction that locks the free-wheel, so that further motion in reverse is impossible.

Vehicles fitted with this gear can be controlled entirely by means of the accelerator and the brake pedal, since a separate control is not required for reversing. Initial movement of the brake pedal applies the dynamic brake, that is, braking by the engine, and only when maximum retardation is required, need the wheel brakes be applied. This gives effective control of the car on hills and reduces wear on the brakes.

Fig. 6. A swinging arm and tapered disc sub-assembly

The manufacturers state that a report received from Dr. Porsche, copies of which are available, confirms that the Beier transmission in the Volkswagen car performed extremely well and fulfilled all claims made for it. By comparison with automatic transmissions based on hydrodynamic drives, the mechanical efficiency of the Beier type of transmission is relatively high. An efficiency of 85 per cent can be expected of a hydrodynamic drive running at a transmission ratio of 2 : 1, but it is liable to fall off rapidly at higher or lower ratios and may be no more than 65 per cent at 1·3 : 1. The curves given for the Beier gear show that the efficiency is 95 per cent just before direct drive is engaged and at a ratio of 2 : 1 the efficiency is 88 per cent.

Modifications can be made to the design to suit special requirements, for instance, a positive neutral. Many components can also be made interchangeable between different size units so that they are common to a range.

FURNACE ELEMENTS

An Important Silicon Carbide Development

IN recent years the use of silicon carbide electric heating elements for high temperature furnaces has greatly increased. They have many advantages over metallic elements. For example, they can be operated at high temperature and watt loadings and can be brought quickly up to temperature without the need of any complicated control system. They can also be used in conjunction with all the normal type of refractories, and do not require protection in special atmospheres. Finally, they are comparatively inexpensive. Nevertheless, they have hitherto also suffered from disadvantages, perhaps the most important of which is that their useful life is generally short. Furthermore, this country has, up to now, been dependent on imported elements.

The Morgan Crucible Company Ltd. of Battersea Works, London, S.W.11, with its extensive knowledge of refractories and experience in furnace and foundry practice has now succeeded in improving this type of element. Many years of research and development work have resulted in the production of a new silicon carbide element which is being marketed under the name of Crusilite. This is a one-piece silicon carbide tube produced by a completely new method, in which the central hot zone is in the form of a spiral of the requisite length.

It is entirely suitable for working over a wide range of element temperature from 800 deg C to 1575 deg C (1472 deg F to 2867 deg F), and its rate of increase of resistance in use is relatively slow. This shows a considerable advance on the earlier types of silicon carbide elements, which invariably showed a rapid increase of resistance in use. Known as "ageing," this characteristic necessitated elaborate electrical arrangements to provide the voltage reserve needed to maintain the required power input. Even so, frequent replacement of the elements was necessary every time their resistance rose beyond the capacity of the power supply to provide adequate radiated wattage. Crusilite "ages" more slowly and therefore it can be operated for very much longer without replacement.

As it is in one piece it is stronger, too, than the other types of silicon carbide elements, which have, in the past, always been made in three sections, the hot zone being of a different material from the cold ends. The cemented joints have been a frequent source of failure, and distortion when heated has been not uncommon. Crusilite does not suffer from these defects; it has no joints to fail.

Such is the strength of the material used in its manufacture that a highly efficient terminal arrangement can be used. At present available for the 10 and 14 mm diameter elements only, it consists of special metal terminal caps shrunk on to the metallized ends of the elements. Although in some furnaces where space is restricted, it may not be possible to make use of these terminal caps—in which case the elements can be supplied with metallized ends only—it is hoped that users will take advantage of them. In designing a new furnace it is particularly advisable that provision should be made for this improved terminal arrangement to ensure trouble free operation.

Not only do the shrunk-on terminal caps assure a good electrical contact with the silicon carbide but they also provide an easy means of connection to the power supply. Two nuts are fitted to the threaded pillar which is an integral part of each cap. To connect to the supply it is only necessary to attach the flex or braid to the pillar and to screw the outer nut onto it. If the inner nut is held by a spanner during this operation, the element cannot rotate and in fact, no strain is put on the element in any direction. The use of these terminal caps, therefore, also reduces the risk of element breakage during installation.

The method of manufacture of Crusilite enables the elements to be made over a range of resistance, and suitable resistance values are held in stock to cover the electrical conditions most frequently met in common practice. Despatches from manufacturer's stock will be within a tolerance of ±10 per cent of the nominal, but the resistance of all elements supplied as a set for any particular furnace will not vary by more than ±5 per cent of the mean, and, in many cases, by considerably less. This narrow tolerance is of great advantage to users. It ensures even heating throughout the furnace and is particularly valuable when elements are connected in series.

The introduction of Crusilite should give furnace designers and manufacturers of high temperature electric furnaces the necessary confidence—which has hitherto been lacking—to proceed with further development work, whilst the user is now assured of a steady supply, with no delivery worries, of a reliable and economical heating element.

COLD WORKING LUBRICANT

A Process With Many Applications

A NEW metal treating process (chemical process) which greatly extends lubrication limits in the cold working of steel, has recently been developed by the Pennsylvania Salt Manufacturing Company in the U.S. Designated as the "Pennsalt Foscoat Process," it consists in cleaning, pickling and applying a new phosphate coating and specially developed lubricants to steel. A heat-resistant lubricating surface is produced. It is chemically interlocked with the steel and, therefore, possesses exceptional adherence even under the most severe working conditions.

It was to improve earlier German work in cold extrusion that the new phosphate coating chemical bath was developed by researchers of the Heintz Manufacturing Company of Philadelphia. Joint research conducted by Pennsalt and Heintz has resulted in the evolution of the carefully integrated Foscoat metal preparation process.

The efficiency of the new process has been successfully demonstrated in cold extrusion. The next step awaits the general availability of press equipment of sufficient size and designed to take advantage of the raised lubrication limits. But of more immediate importance to industry are the remarkable results which have been attained in such applications as tube drawing, wire drawing, deep drawing (ironing), deep stamping, and similar cold working operations. In these operations there generally exist two limitations—lubrication and the ductility of the metal. The first of these is virtually eliminated by the chemically bonded lubrication film imparted to steel surfaces by the process.

Significant economies resulting from this improvement in lubrication include elimination of intermediate press operations, as well as annealing and chemical treating operations; reduced consumption of chemicals because of compatibility; increased production with existing equipment; savings in metal or reduction in scrap losses, and considerable extension in the life of costly dies.

In wet drawing of fine steel wire, for example, commercial application of the new process resulted in a 40 per cent increase in the rate of production — actually to the highest rate of capacity of the drawing equipment. Despite this speed-up, die life was increased 2½ times. In dry drawing of steel wire shapes, such as triangle and square wire, from round stock, one application of the process permitted drawing to finished shape without the intermediate anneals and re-coating required in previous processes.

Production use of the Foscoat Process at Heintz Manufacturing Co. has made possible substantial economies in the fabrication of automatic washing machine tubs. Reductions in scrap losses due to rejects and in downtime for stoning of dies have resulted in an increase of 140 per cent in output. In deep drawing (ironing) of steel cartridge cases, 80 per cent reductions in wall thickness in the metal were possible with a single application of the new process without intermediate annealing. This represents a 100 per cent improvement over conventional practice.

In actual production in rod-pulled tube drawing, overall reductions of 80 per cent were achieved with a single application of the Foscoat Process, or about 60 per cent improvement over that previously obtained. In another tube mill, using plug-drawing, overall reductions of 60 per cent were obtained with one application of Foscoat, which is also a 60 per cent increase over existing practice.

Even greater savings are in prospect in commercial cold extrusion, for the process can often eliminate the necessity for forging or upsetting of heated billets. These operations generally require a starting billet twice the size of that necessary for cold extrusion.

Savings are also possible by adapting plain carbon steel for applications ordinarily requiring steels containing critical and expensive alloying materials. Cold extrusion involves the concept of steel as a plastic material which, when the barriers of friction are sufficiently extended, will flow under pressure. Stressing the steel in compression—in contrast to cold drawing where forming is performed by stressing the metal in tension—permits a drastic kneading action that increases strength characteristics considerably, with but slight effect on ductility.

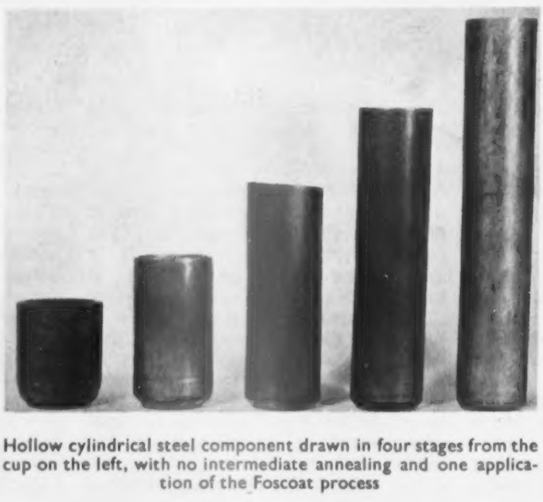
Cold extrusion, made possible by improvements and modifications to phosphate coating techniques, was developed and used in Germany during World War II, principally as a steel-saving device, to produce cartridge cases, other ammunition components, gun barrels, airplane parts and other tubular or cylindrical bodies.

Immediately after the war, realizing its potential value to America, Heintz engineers studied German methods, correlated data and, with the aid of German technicians, carried out several research contracts for the United States Government. This preliminary work forms the basis for cold extrusion developments in the United States. Subsequently, Heintz technicians developed the new phosphate coating and lubricant around which the Foscoat process has been built.

But because the process required compatible metal treatment chemicals, and because Pennsalt had wide experience in this field and was equipped to produce a complete line of products integrated in one process, Heintz turned its development over to Pennsalt for further research. It was in this research and development that the present Foscoat process was evolved.

Foscoat is a specially formulated phosphate coating which can be applied by immersion, flooding or spraying, and forms a strong, adherent coating chemically bonded to the steel. This highly adsorbent coating functions as a host for Foslube, an organic lubricant which is designed to react chemically with the Foscoat, in addition to being physically adsorbed and absorbed. The combined action gives a heat-resistant surface interlocked with the metal and which has exceptional adherence even under the most severe working conditions. In view of the importance of proper precleaning and preparation for cold working, the complete process was worked out to include pickling and special alkaline cleaners.

While the process is already being used in regular operation in various cold working plants, Pennsalt's immediate objective is to extend it to other cold working operations where it may be applicable.



Hollow cylindrical steel component drawn in four stages from the cup on the left, with no intermediate annealing and one application of the Foscoat process

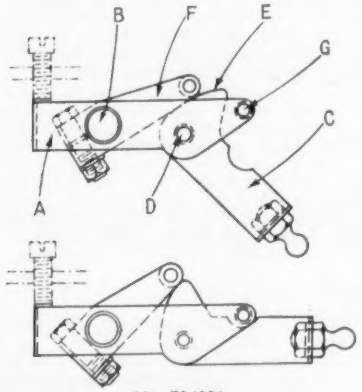
CURRENT PATENTS

A Review of Recent Automobile Specifications

Compound throttle lever

IN vehicles of relatively high power: weight ratio, initial opening of the engine throttle valve may cause an undesirable snatching effect, especially when one of the lower gears is engaged or if an undue amount of back-lash has developed in the transmission. To obviate this, it is proposed to fit a compound throttle lever by which initial opening of the throttle is effected by a cam action giving sensitive control and a smooth build-up of power.

The main lever A is a substantially



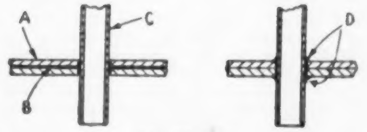
No. 704801

rectangular frame journalled between its ends on the throttle valve spindle B. A cam lever C is pivotally mounted on the main lever at D so that its cam nose E co-acts with a roller at the extremity of throttle lever F. Lever C is permitted a limited amount of independent movement before it engages an abutment G on the end of lever A. The usual ball stud for connection to the throttle linkage is secured to the end of the lever C. *Patent No.* 704801. *S.U. Carburetter Co. Ltd.*

Bonding heat exchanger elements

TO effect a fluid-tight junction between tubular and plate elements of, for example, an aluminium heat exchanger, a bonding medium of the thermosetting resin type, such as "Araldite," is used. The header plate A comprises two sheets of aluminium alloy with an intervening layer B of thermosetting resin, only partially cured in order to secure the sheets while they are bored to receive the tubes C. Only a small clearance is arranged for the tubes in the holes and, after insertion, the assembly is subjected to a heating process while the two header plates are pressed together. The resin is forced from between the plates into the clearance around the tubes, as at D, and in this position is completely cured to consolidate the joint

If sufficiently close tolerances are held it may not be necessary to apply pressure as capillary attraction will cause the resin to flow freely between the joint surfaces. A thermosetting resin is also of advantage in bonding elements of dissimilar metals, since it provides the insulation necessary to prevent electrolytic corrosion. The



No. 705569

method, however, is not limited to a resin bond, and for metal assemblies solder, copper, or other brazing material may be used. *Patent No.* 705569. *Imperial Chemical Industries, Ltd.*

Air-cooled, two-stroke diesel engine

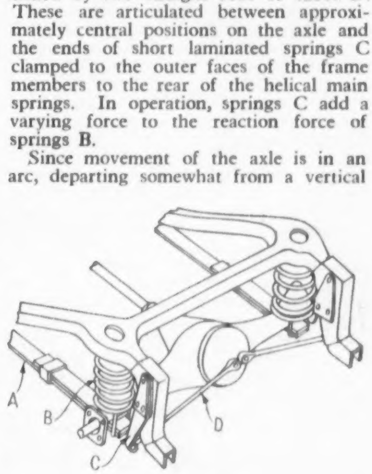
THE object of this form of construction for the cylinders of a loop-scavenged two-stroke engine is to avoid heavy metal sections in way of the port belt and thus obviate the risk of deformation under thermal stressing. Secured to the main engine block by through bolts A, the cylinder casing B supports the upper part C of the cylinder head attached by four bolts D. The head proper is clamped between C and the cylinder by eight bolts E. In the port belt, the scavenge and exhaust apertures are of the same axial length and positioned at the same level and are thus accommodated in a relatively narrow annulus giving a minimum interference with the finning of the cylinder.

Cooling air passes over the cylinder by way of orifices F above and G below the port belt. To facilitate cooling in the region of the exhaust duct, passages H and J are provided in the cylinder casing and the cylinder respectively. Scavenging air is supplied from longitudinal ducts K in the engine block. *Patent No.* 705379. *Klockner - Humboldt - Deutz, A.G.* (*Germany*).

Rear suspension

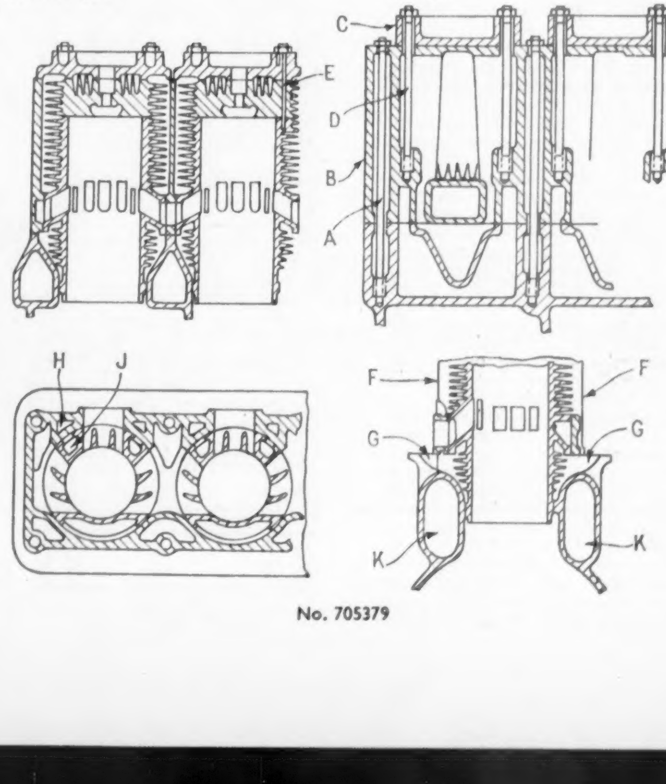
IN this suspension a rigid rear axle mounted on helical springs is stabilized resiliently in the transverse direction. The axle casing is linked to the vehicle frame by longitudinal members A and is free to oscillate against the constraint of springs B. Transversely, the connection between the axle and the frame is established by two straight rods or tubes D. These are articulated between approximately central positions on the axle and the ends of short laminated springs C clamped to the outer faces of the frame members to the rear of the helical main springs. In operation, springs C add a varying force to the reaction force of springs B.

Since movement of the axle is in an arc, departing somewhat from a vertical



No. 705563

transverse plane, the rods D are subjected to torque stresses and consequently are furnished with resilient rubber bushings at the end connections. The springs C are arranged to diverge downwardly. *Patent No.* 705563. *Fiat Società per Azioni* (*Italy*).



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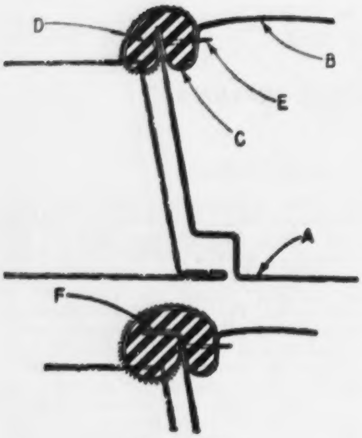


No. 704990

Sealing vehicle doors

THIS bilobular sealing strip, of sponge rubber or similar resilient material wholly or in part covered with fabric, is inexpensive, readily applied and firmly retained in position. The door post consists of an outer panel A, formed with a corner rebate and a jamb rail, and an inner finishing strip B having a U-shaped marginal recess C. Spot welds secure the outer limb of the recess to the margin of the jamb rail. One lobe of the sealing strip D is seated in the recess and retained by a suitable adhesive. If desired, additional security is obtained by a number of drive nails E. The other lobe lies closely against the outer face of the jamb rail and in way of the inner corner of the door.

In a modification, both the jamb rail and the outer limb of the recess in the finishing strip are furnished with contiguous flanges F, also spot welded, and the sealing strip is formed with an angled recess between the two lobes to embrace the flanged margin of the post. *Patent No.* 704990. *Pressed Steel Co. Ltd.*

Spark ignition, fuel injection engine

A DISC-SHAPED combustion chamber providing a compression air swirl of high velocity is the characteristic feature of this engine in which combustion is independent of the spontaneous ignition quality of the fuel and knocking is prevented. In the working cylinder the flat-topped piston has only a mechanical clearance from the face of the cylinder head in which the shallow disc-shaped combustion chamber A is arranged in a vertical, longitudinal plane offset from the cylinder axis. The diameter of the chamber is only slightly less than that of the cylinder and the compression ratio may be from 8:1 to 13:1. Inlet valve B and exhaust valve C, seated centrally in the opposite walls of the chamber, lie in a horizontal, transverse plane.

Communication between cylinder and chamber is by a throat D arranged with its axis tangential to a circle concentric with, but of substantially less diameter than, the periphery of the chamber. The cross-sectional area of the throat is proportioned to produce in the cylinder a pressure of from 25 to 50 lb/in^2 above that in the chamber at the commencement of fuel injection in order to maintain the directed air flow during the initial stage of combustion. Fuel is injected by a nozzle E spraying downstream of the air swirl, as shown. The spark plug F is mounted 30 deg to 45 deg downstream of the injector. Ignition is timed to be simultaneous with the commencement of injection.

Combustion is initiated on the electrical ignition of the first increment of fuel injected and a flame front is established between the spark plug and the centre of the chamber. Flame propagation is impeded by the maintained air swirl and also by encountering excessively rich mixture as the front tends to approach the injection nozzle. The practical effect is to maintain the flame front in its position relative to the plug and injector nozzle whilst it travels counter to the air swirl until injection is completed and the piston reaches top dead centre.

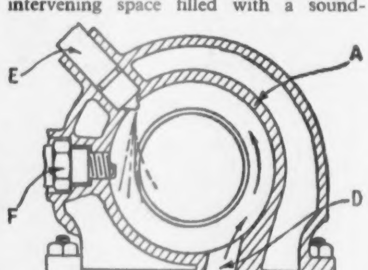
The specification also includes descriptions of three two-stroke engines; a port-scavenged unit with a lateral, vertical chamber, a valve-scavenged engine with a lateral, horizontal chamber and a loop-scavenged design with the chamber vertical in the cylinder head. *Patent No.* 704800. *Texaco Development Corporation (U.S.A.).*

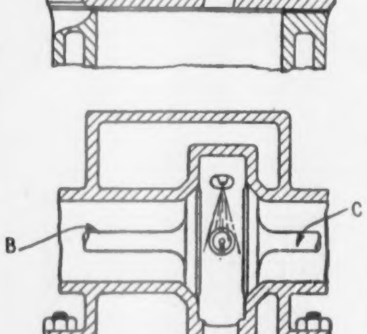
Silencing an air-heating system

WITH a vehicle warming system in which air is heated from the coolant radiator and the exhaust system, disturbing noises, originating in the exhaust manifold as well as being produced by the air flow, may be transmitted to the interior of the vehicle. Such noises are almost eliminated in this arrangement, which is claimed to be particularly effective against the transmission of high frequencies.

The engine exhaust manifold A is enveloped by an air-heating conduit B having at its forward end an intake cone C to receive air from behind the radiator fan. Constructed of sheet metal, this conduit has spaced double walls, the inner wall being slotted or perforated and the intervening space filled with a sound-damping material, such as glass wool. From the conduit the heated air flows through a duct D to a distribution chamber E on which is fitted a flap F, controllable by the driver, admitting air to the vehicle body in the space forward of the driving seat. A branch duct G leads to nozzles at the base of the windscreen for demisting or defrosting purposes.

In the diagram warm air is being delivered to the body space and also to the windscreen nozzles. By closing flap F all the air can be directed to the windscreen and by manipulating control H the flap J in duct D may be opened to divert some or all of the air to the engine compartment or, if desired, through a duct to the exterior of the vehicle. *Patent No.* 705091. *Daimler-Benz A.G. (Germany).*





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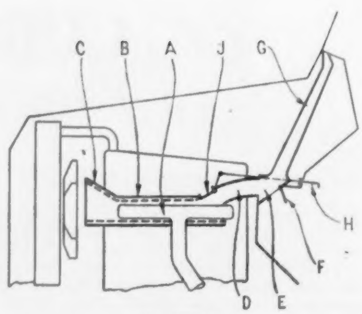

No. 705091

Electro-deburring

THE usual sulphuric acid-phosphoric acid bath used to polish steel to a bright, lustrous finish will not produce such satisfactory deburring as is generally required. An addition of chromic acid will effect some improvement but imposes a limit on the period of time that the bath can produce simultaneously acceptable polishing and deburring. This is attributed to the formation, in cyclic oxidation and reduction, of too much trivalent iron and trivalent chromium. For continuous and simultaneous polishing and deburring, a suitable concentration of a trivalent metal, substantially unaffected by cyclic operation, is required.

It is claimed that the introduction of a small amount of dissolved, stable, trivalent metal in mineral acid baths will produce the desired results on plain carbon steels and alloy steels containing not more than 6 per cent of combined alloying ingredients. Aluminium, tungsten, titanium, molybdenum and zirconium are considered suitable, to the amount of 0·1 to 3·0 per cent by weight of the bath. Should chromium be included, to enhance the lustre of the polish, the aluminium concentration should be from 0·3 to 1·8 per cent and chromium form the balance up to a maximum of 3·0 per cent. A chromium-containing bath is undesirable if the articles being treated are to be subsequently nickel plated, as chromium may be carried over with ill effect.

The anode current density can vary from 50 to 500 amp/ft^2 at temperatures from 100 to 250 deg F. Preferred ranges are from 75 to 200 amp/ft^2 at 150 to 220 deg F. During the operation, iron dissolved from the work in the trivalent form, is reduced to ferrous iron at the cathodes, is continuously precipitated, and can be removed by filtration. Representative bath compositions and treatments are detailed in the specification. *Patent No.* 704945. *Société Jacquet-Hispano Suiza (France).*

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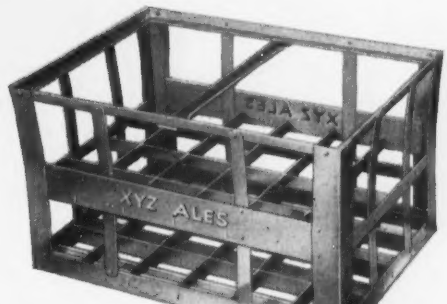

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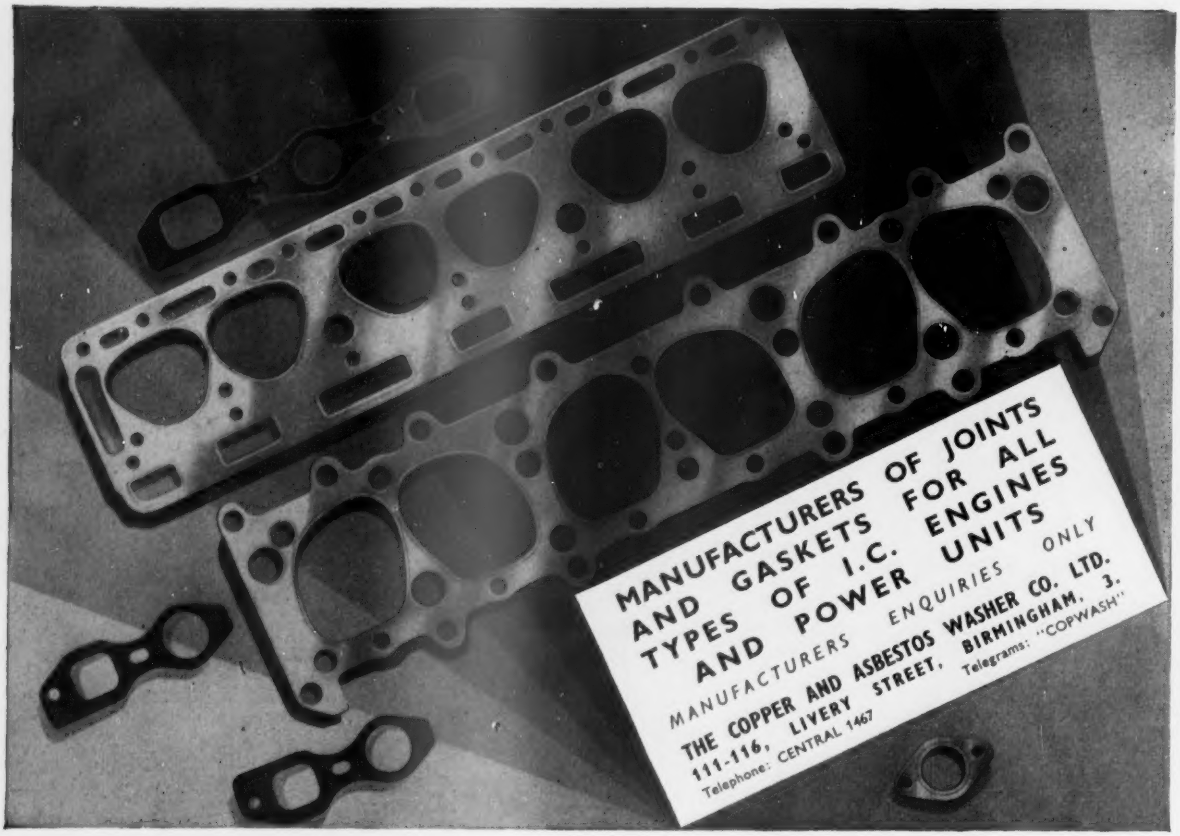

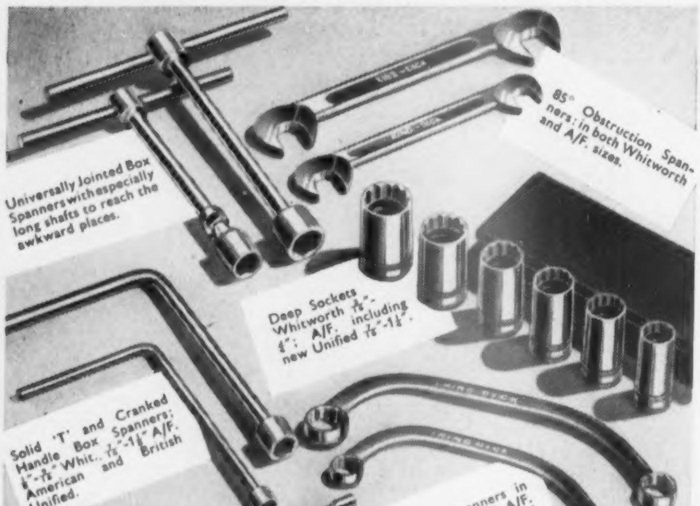

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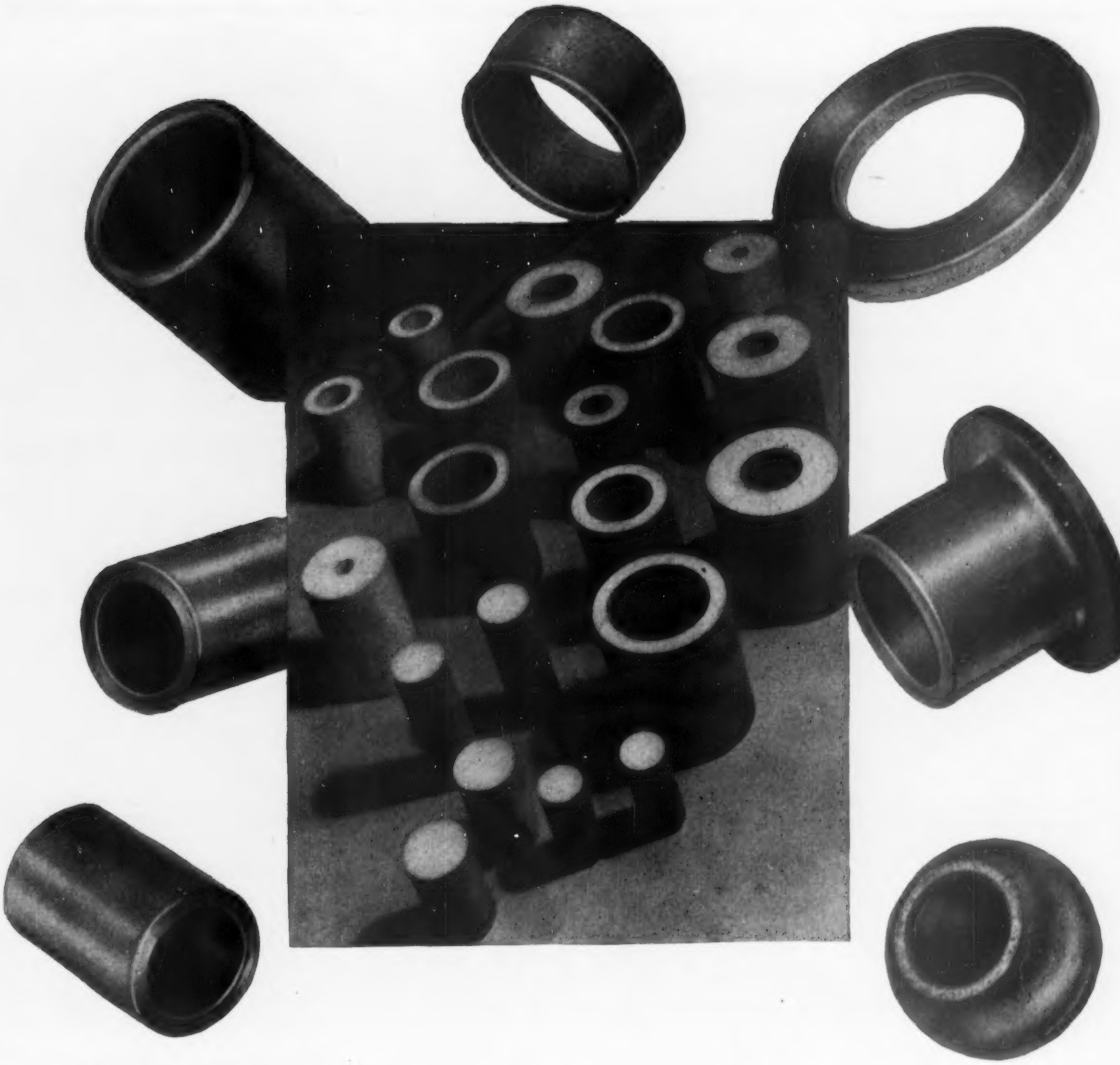

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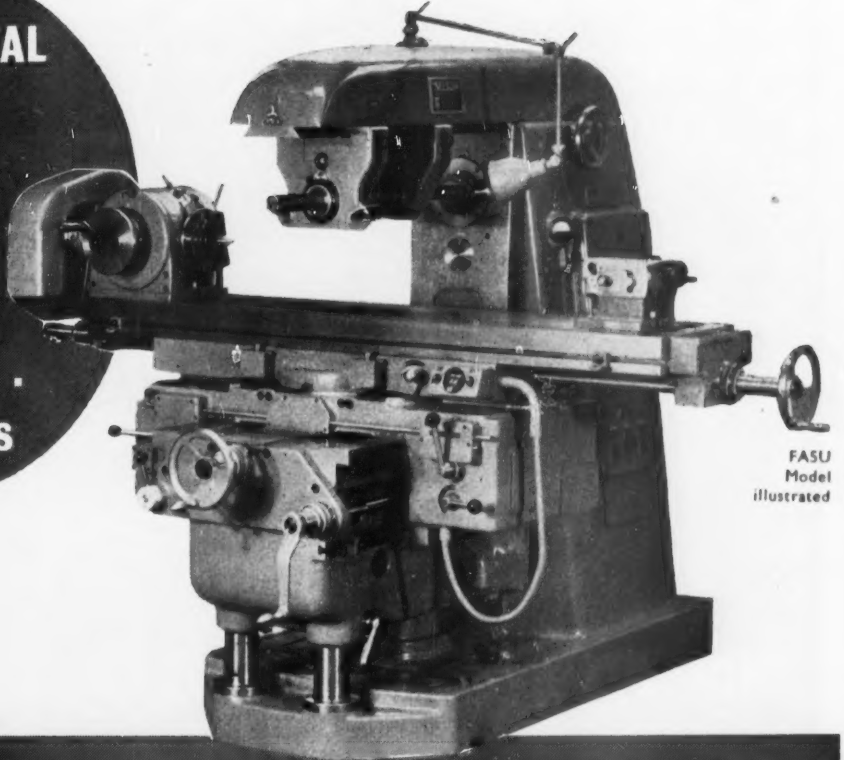

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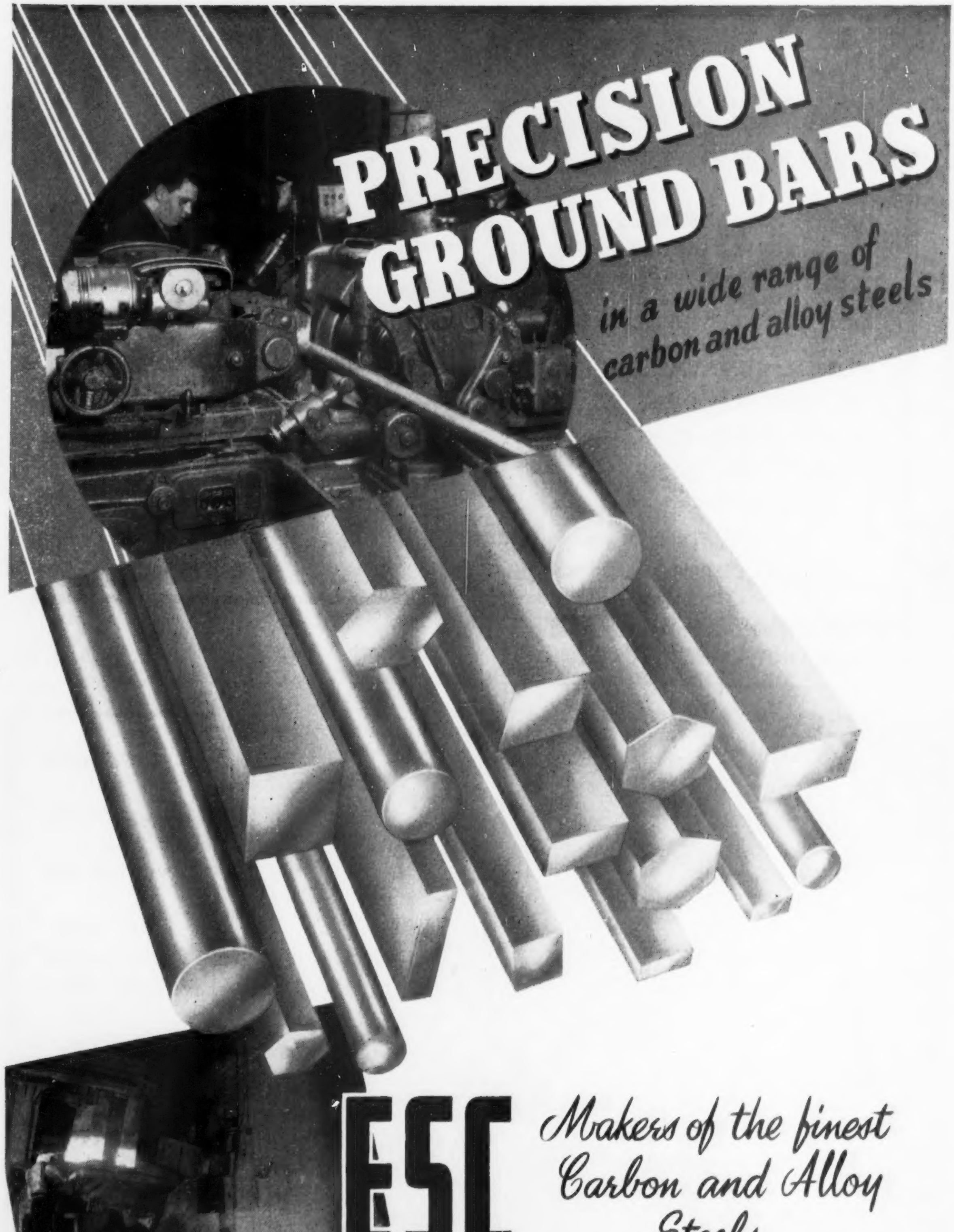
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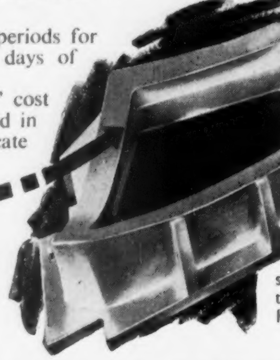
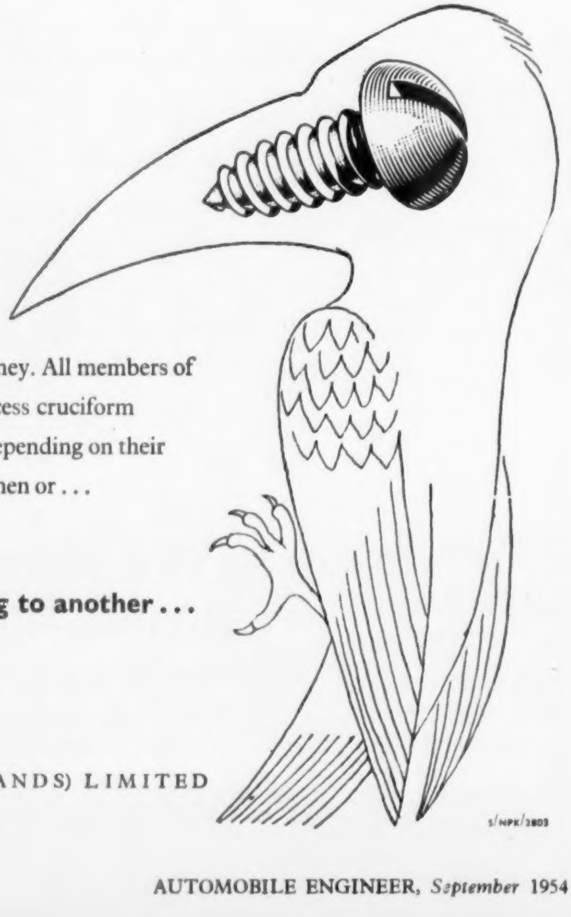
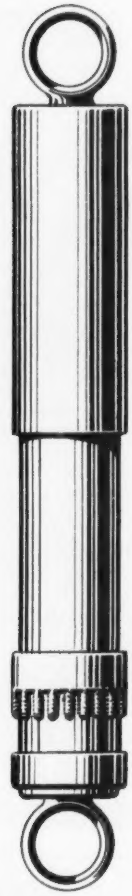
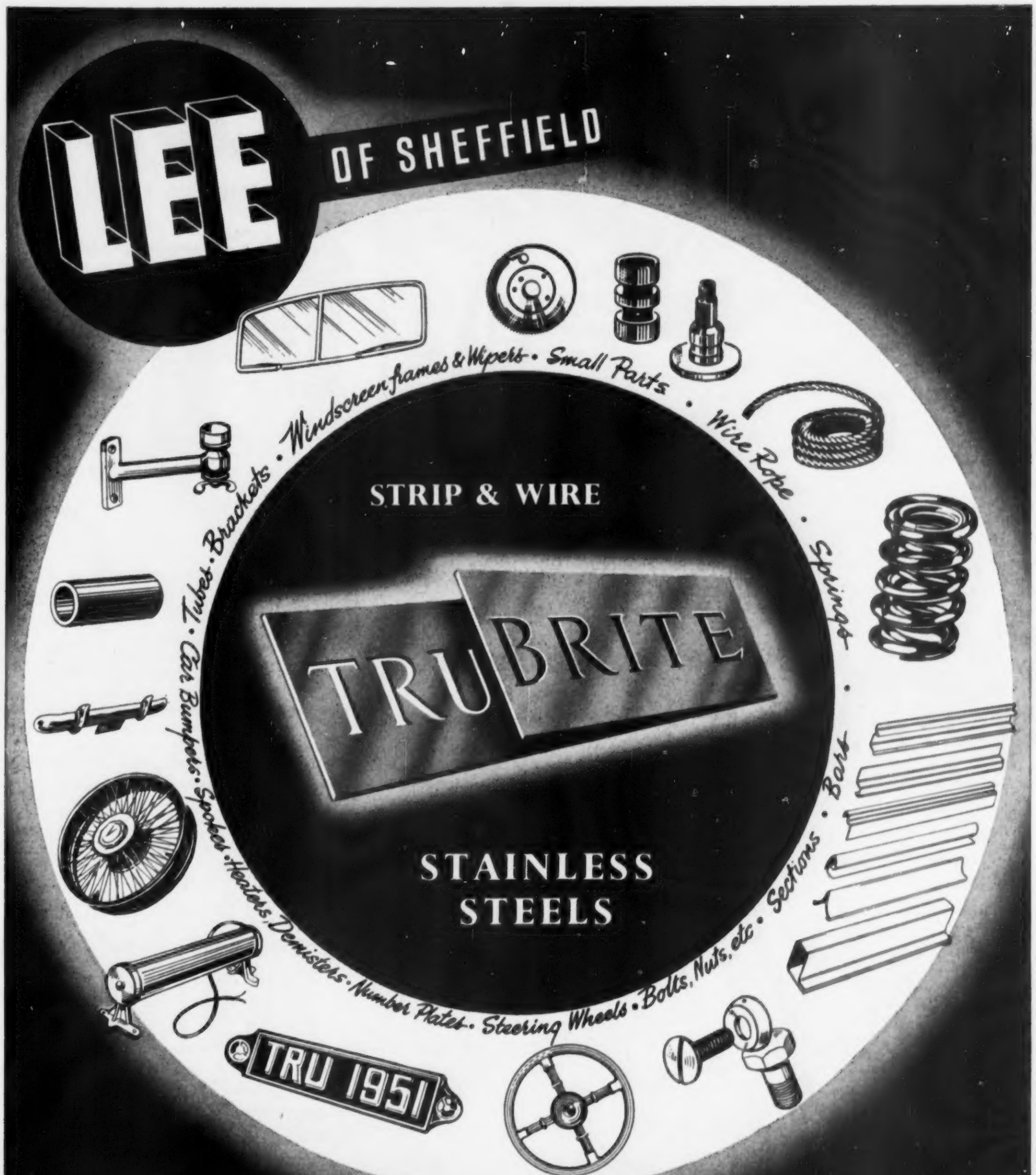


Die for sheet-steel. Courtesy of the Willenhall Motor Radiator Co. Ltd.



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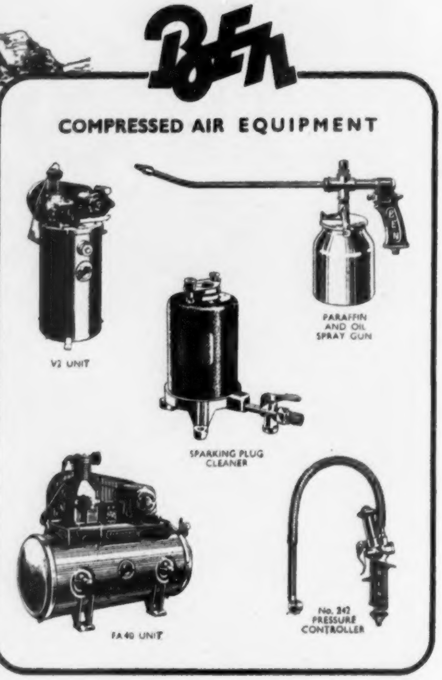

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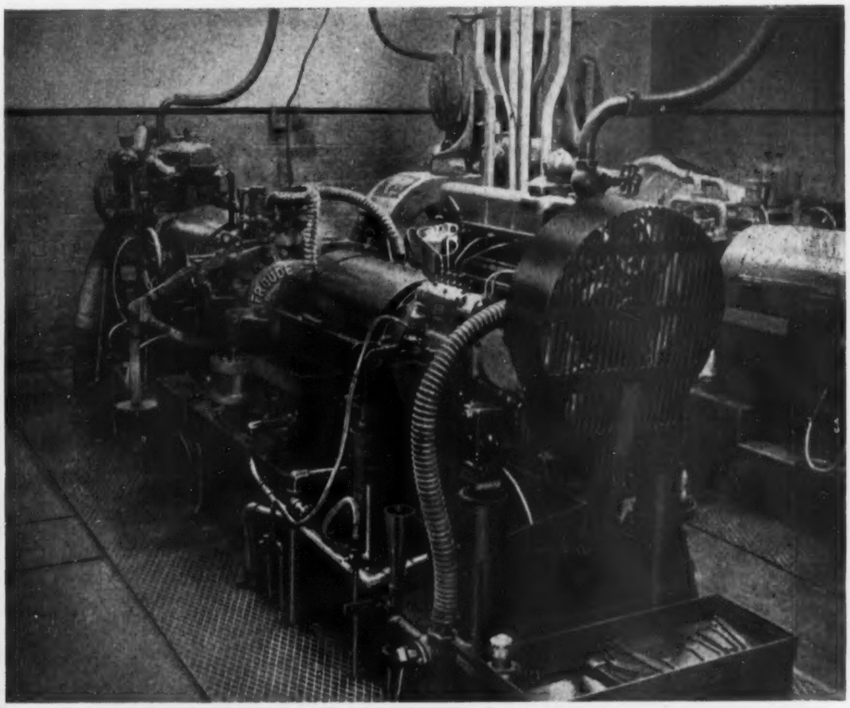

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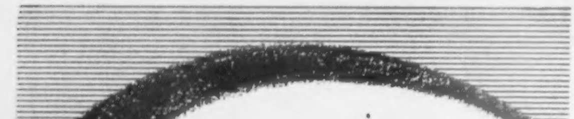

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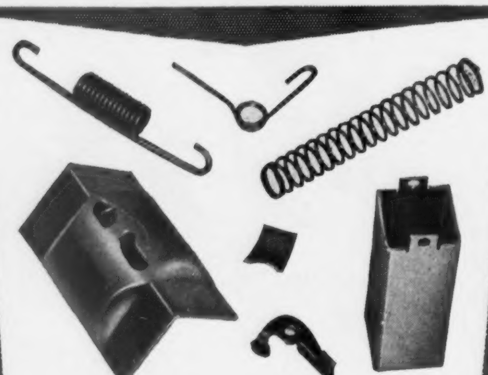

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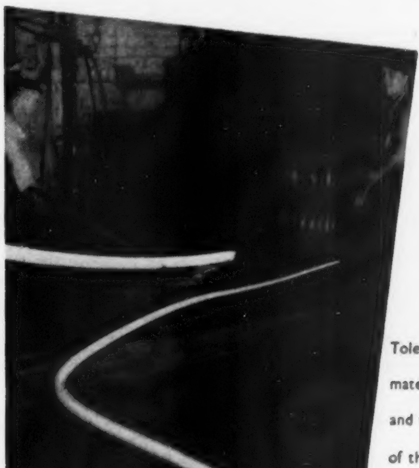

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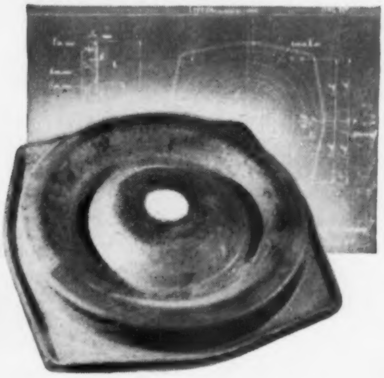

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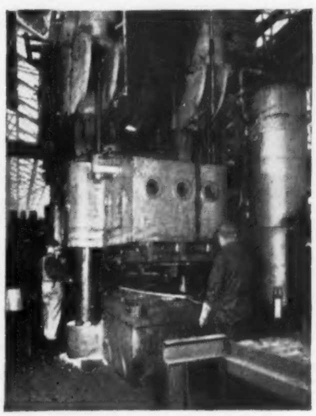

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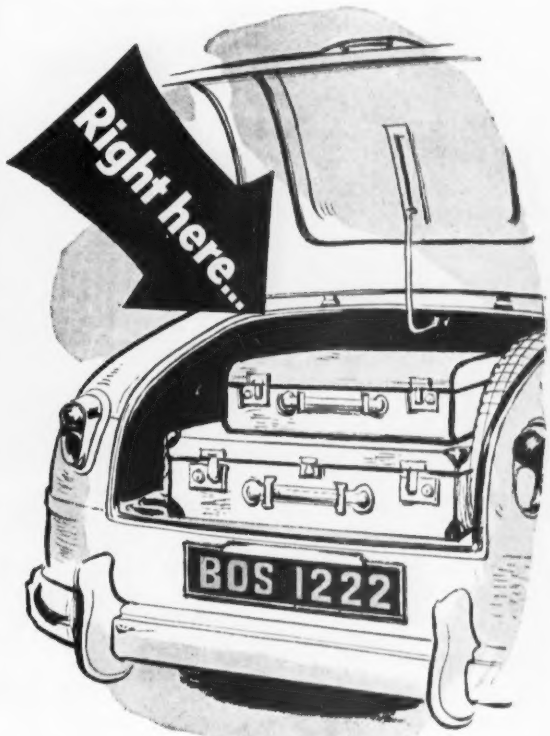

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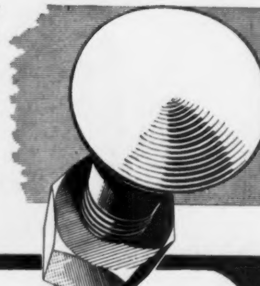

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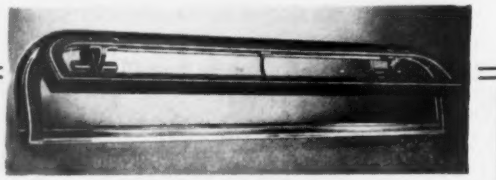

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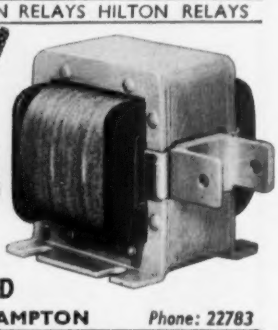

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